8-2017

Assessment of South Carolina's Department of Transportation (SCDOT's) Readiness to Perform Data Driven Safety Assessments

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ASSESSMENT OF SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION'S (SCDOT'S) READINESS TO PERFORM DATA DRIVEN SAFETY ASSESSMENTS

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Civil Engineering

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by
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August 2017

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ABSTRACT

Under MAP-21 federally mandated requirements, the Moving Ahead for Progress in the 21st Century (MAP-21), South Carolina is implementing a data-driven based safety decisions and roadway safety performance, which is highly evaluated based on the assessment of safety related information including roadway, traffic, and crash data. Roadway characteristics and Traffic data in most case a subset of the Model Inventory Management System (MIRE) version 1.0 for roadway and traffic data, or from Minimum Model Uniformity Crash Criteria (MMUCC) for crash data. For all that, this thesis involves analyzing and investigating the state-of the-practice and the state-of-the-art of the current SCDOT roadways, traffic, and crash data inventories to test the readiness of building an effective and efficient data driven safety required by the new legislated MAP-21.

The research team identified gaps in the current data and suggested a potential data set with priorities based on safety data reporting needs per two commonly federally mandated reporting programs (MIRE fundamental data and HPMS full extend), and one analysis tool (HSM required data). Six performance measures (e.g., accuracy, completeness, and uniformity) were employed to evaluate the ability of using the current data as a prerequisite to extend the data scope to include state-wide roadway network including local roads. Then, the previous successful implementation of data collection using technologies such as LiDAR and Air Imagery were tested on wither they can provide means to surpass the limitations of collecting safety data.

In our analysis, we discussed a multi-phased approach which was utilized to organize the safety data requirements and identify the SCDOT data characteristics. This process can be used to enhance the state's safety driven data assessment on the roadway network. A number of specific tasks were undertaken towards achieving the objectives discussed earlier.

The results in this work found that most previous reporting was based on the Highway Performance Measures System (HPMS) recommendations, which does not cover local roads, given higher crash rates occur on local roads. The results of this research also emphasized a common relationship between the roadway characteristics, traffic conditions, and the crash rates to conduct a data driven safety assessment on the State's highways. Thus, it is crucial to build a state-wide strategic plan to improve the performance measures (i.e., accuracy, completeness, and uniformity) of the recent data and expand the future data capabilities using new technologies to achieve the new safety goals put up by federal agencies.

Investigating the usage of data driven approach for safety analysis has led to several findings regarding the importance of linking roadway segment characteristics (including local roads) and crash locations, which represents a major key in understanding safety issues on the related roadways features. This highly suggests the need for developing more comprehensive data plans in the SCODT. Based on this analysis, the previously used technologies such as LiDAR and Arial Imagery found to be promising for new additions to the safety data collection process, where most roadway characteristics and some traffic controls data were collected successfully in UDOT in LiDAR technology.

MIRE and MMUC data elements identified in gap analysis and not collected in SCDOT are prioritized based on their importance for safety analysis and provided in this study for future implementation of data collection plans in South Carolina.

DEDICATION

I would like to dedicate this work for my mother and father, Shadiyah Mahmood and Abdulqader Ali, for their kindness, endless love, and support which have taught me how to never give up, and will be a continues source of inspiration to me.

ACKNOWLEDGMENTS

I would like to deeply thank my advisor, Dr. Jennifer H. Ogle, who has given me this opportunity and support, motivation, and mentored me for the last 2 years as a master's student. It was a privilege to work under her supervision and I will never forget how she believed in me even though coming from mathematical background to civil engineering, which made my study more challenging.

I would also thank Dr. Mashrur Chowdhury and Dr. Wayne Sarasua for accepting to serve in my committee. I am thankful for them their support, guidance, and providing valuable insights which helped improve this work.

I would like to specially thank my husband, Aws A. Ajaaj, who has giving me support, love, and ease during this journey of pursuing my dream in getting Master degree. He was the one who took care of me and the kids during my busy days. I could not accomplish this without him being beside me.

I would like to acknowledge my brothers, Abdul Hadi, Abdul Allah, Aldul Wadood, Taha, Ammar, Umer, and Abdul Hafidh, for the continues encouragements during hardships. I also want to extent my appreciation for Mr. Mahdi Rajabi, for his help in clearing out many issues about the data and giving suggestions that made the research better. Moreover, I thank Mrs. Marva Coefee for her help in improving my English skills when I desperately needed someone to help on that.

Finally, I am grateful the staff members of Glenn Department of Civil Engineering for the welcoming atmosphere and the extended help with any type of administrative service they provided.

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CHAPTER ONE

INTRODUCTION

1.1 Background and Problem Statement

One major part of a new legislation, known as Moving Ahead for Progress in the 21st Century (MAP-21), is to support data-driven safety decisions and roadway safety performance which is highly evaluated based on the assessment of roadway data (A Summary of Highway Provisions Report, 2012). Under MAP-21, a dramatic transformation in policies and programmatic frameworks must be made to increase the safety and reduce rashes of motor vehicle on all national highways including local roadways. This transformation creates transitions to the current for state's DOT's state-of-the-practice roadways safety management by rolling several existing programs (e.g., National Highway Performance Program (NHPP), Surface Transportation Program (STP), Highway Safety Improvement Program (HSIP), and others) into a new core formula program structure. This role would ultimately require an advancement in the States capabilities for safety data collection, analysis, and integration in a manner that complements State highway safety programs and commercial vehicle safety plans. Towards this objective, the South Carolina Department of Transportation (SCDOT) is now putting together the final rule to address the minimum requirements established by MAP-21 which will undoubtedly help deriving the redevelopment of database and safety management system in the DOT's nationally.

In South Carolina (SC), the number of traffic fatalities was 823 in 2014 and 53,029 reported injuries, while the cost from motor vehicle crashes alone is over 7$ billion. The trend in fatal crashes has increased from 1.8% between 2004-2007 to 5.1% between 2013-2014, making SC the 3rd highest crash rates nations wide (Crash Report Fact Sheet, 2007, 2014). These statistics raise the question concerning the safety performance on State's roadways and challenge the SDCOT to find the optimal solutions to reduce the increasing number of crashes especially with the new legislation requirements.

The data necessary for safety analysis (Roadway characteristic, Traffic, and crash data) are essential to make sound decisions for improving the design and operation of highways. Safety data comprise of different categories ranging from historical crashes and traffic exposure, to geometric design and driver demographics. Recent safety analysis tools such as the Interactive Highway Safety Design Model (IHSDM), the Highway Safety Manual (HSM) and Data and Analysis Guide have specific data requirements that most of the state DOT's do not maintain (Sarasua et.al, 2015; Ogle, 2007). Figure 1.1 shows the role for some examples of roadway safety analysis tools and the main driving data inputs.

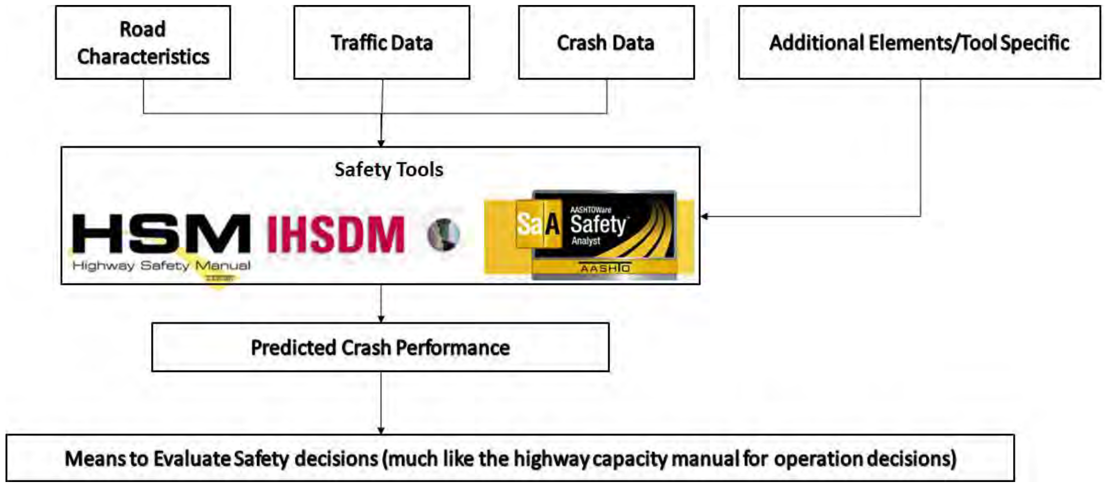

Figure 1.1: The role of some roadway safety tools and main driving inputs

Bases on the transportation infrastructure task force report (2012), the SCDOT is responsible for controlling 65 percent of the total roadways in South Carolina. Historically, the information about asset inventory has been maintained in a mainframe-based application with limited user access across the SCDOT enterprise. Data accessibility was very limited to only employees with deep experience about the data mainframe application and the data structure. Also, this process needs time and resources to inventorying various DOT assets such as guard rail, marking, road width and pavement conditions. In support to increase data accessibility for more employees, SCDOT sought the need to upgrade the roadway inventory to Oracle-based Roadway Information Management System (RIMS). Although, RIMS database simplified managing of the inventory and associated roadway assets, it cannot currently accommodate with other systems that provide asset data. Besides the indusial elements in RIMS data do not always meet the need of alternate users in other departments. For example, RIMS database provides the information only for mainstreaming and has the carriageway geometry problem which makes it not necessarily matching the real road maps (GIS maps) and/or with the data provided by the roadway data collected from different counties. In addition, the roadways with side parking in RIMS database, which are very important in safety studies, are recorded as a 2-lane roadway with 20 feet linewidth on both sides of the roadways.

In addition to RIMS, the DOT maintains several databases to support specific business operations. One example is the e-TEAMS database which houses information regarding traffic signal for state maintained roadways. The database includes a spatial record of location for each signalized intersection with very basic information regarding the signal itself. Attached to the database are signal plans for a good number, but by no means all, of the signals. The database does have a login making it available throughout the DOT, but it is disconnected from the data contained in RIMS. While this is much better than having to locate paper plans, the information in the plan files must be viewed manually and it is not complete.

Currently, there are federal mandates for reporting on bridges and pavements, safety, and traffic volumes among others. Over the coming months, additional data requirements are expected to arise from the MAP-21 legislation to support national measures of effectiveness, reporting and the management plans. These requirements will be monitored and will help to define the future of the SCDOT. The Federal Highway Administration (FHWA) has provided a guideline for safety related data elements in the Model Inventory of Roadway Elements (MIRE) document, which is most commonly used for reporting purposes and monitoring the safety performance. The SCDOT, as well as other States, have been hardly working to ensure that asset and safety data are well collected, maintained, and well reported and used for good decisions making. However, these databases require a continues evaluation and research for new data sources (Ogle, 2007; Sarasua et.al, 2015).

1.2 Research Objectives

The primary attention of this study is to provide a guideline to improve the current practices observed by the SCDOT, aiming the improvement in managing four main datasets maintain the SCDOT databases. This ultimately leads to a reduction in the levels of road traffic crashes, the resulting injuries and death toll in South Carolina. These datasets include Model Inventory Roadway Inventory (MIRE), Average Annual Daily Traffic (AADT), e-TEAMS (Intersection data, the explicit name is unknown), and crash data. It is believed that the projected safety enhancement will certainly lead to an improvement in conducting the traffic operations while at the same time limiting the possibility of conflicts. Following are the objectives established for achieving the research purpose effectively:

- **Assess SCDOTs readiness to perform data-driven safety assessments.**
    1. What data sources does the DOT maintain?
    2. Are the existing data accurate, complete, and comprehensive?
    3. Does SCDOT collect/maintain all the federally mandated data elements?
    4. Does SCDOT collect/maintain data needed for new safety analysis tools?
- **Determine gaps in data readiness**

1. What gaps exist between current SCDOT data in comparison to data needs?
2. Does SCDOT need to improve the data they maintain?

- **Provide recommendations and specifications for data collection and maintenance**
  1. Can SCDOT better utilize limited resources for data collection and maintenance?
  2. What best practices can SCDOT adopt from other states

1.3 Benefits of This Research

This research would begin with a synthesis of best-practices for roadway asset inventory development to support future planning, asset management plans, safety analysis and other enterprise data needs. From the synthesis, a data needs inventory would be conducted throughout the department to determine what data elements people currently maintain, which data elements they need but don't have, and which data they no longer need. After all offices, have been surveyed, the data elements would be prioritized based on different reporting safety analysis programs/tools for inclusion in the enterprise data system. The next phase of the project will be to ascertain the technologies that could/should be used to obtain/update data in the system. Many options exist from digital highway measurement vans, laser measurement systems, photogrammetry, etc. The research would finally develop a database specification South Carolina need to consider collection along with their data dictionary and coding.

Crash data analysis from the several corridors of the state will assist in developing standards, guidelines and other policies on safety and operational procedures as well as the economic impacts of it. In addition to this, current research also identifies changes that are suggested to the ARMS (Sarasua et al, 2015). Such changes should help in safety improvements in terms of traffic operations and cost-savings, in the longer run. Moreover, recent study highlights the implementation of the designed program through stating the strategies that are most appropriate in any specific situation. From this study, it is expected that this management program will be communicated with municipalities in order to make their inclusion in the municipal planning possible.

The focus of the study is to improve the transportation and highways system by implementing certain processes to the system. The assessment of the plan requires various initiatives which include identifying leads, developing data program inventory, identifying objectives and goals for the concerned area. Several processes provide firm support to the transportation and highways programs to increase the safety factor and efficiency in the system. Several agencies and Federal units under the legislative rules and regulations govern the processes of safety improvement of the entire system.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

A variety of data sources are necessary to make wide-ranging assessments of the safety performance of South Carolina's roadways. These data include crash reports, exposure data, as well as the inventory data for roadway characteristics. Safety data may also include vehicle registration, history and records of drivers, and adjudication/citation facts, but these are predominantly used for behavioral safety studies and not by transportation departments for assessments of roadway-related safety.

In the last couple of decades, there has been an increased need for more and better data for safety analysis. The requirements are attributed to the advancement of methods and tools for roadway safety performance measurement including:

1. Federal Highway Administration's (FHWA).
2. Interactive Highway Safety Design Model (IHSDM).
3. National Cooperative Highway Research Program (NCHRP).
4. American Association of State and Highway Transportation Official's (AASHTO)
5. Safety Analyst.
6. Highway Safety Manual (HSM).

These tools and analytical methods require significantly more data to achieve the best and precise predictions of safety performance. This literature review provides an information on federal data requirements and best-practices related to safety data management for States' departments of transportation (DOTs). Safety data sources include: 1) roadway inventory – often maintained by states in disparate databases such as cross-sectional element databases, signal databases, and sign/marking databases with All Roads Network Linear Referenced Data (ARNOLD) legislation as the only federal requirement; 2) traffic data – typically derived from the Highway Performance Monitoring System (HPMS), a federally mandated data collection program; and 3) crash data – typically conforming to the Minimum Model of Uniform Crash Criteria (MMUCC) and collected by the public safety office in a state with mandates for fatal crash reporting. Uses of the data in the Highway Safety Manual (HSM) processes are also covered. The review ends with basic information regarding South Carolina data systems as reported from prior research.

2.2 Safety Analysis Programs

2.2.1 Roadway Inventory

The Model Inventory of Road Elements (MIRE) provides a recommended list of roadway characteristics and important design elements for safety and traffic operations management. MIRE is intended as a guideline to help transportation agencies improve their roadway and traffic data inventories. It provides a basis for a standard of what can be considered a good/robust data inventory that helps agencies move towards the use of performance measures to assess data quality. The MAP-21 reauthorizing legislation identifies the need for improved and more robust safety data for better safety analysis to support the development of State's Strategic Highway Safety Plans (SHSPs) and their

Highway Safety Improvement Programs (HSIPs). For safety management, most of the elements in the inventory are critical for predicting the safety of a section of roadway or an intersection.

The Federal Highway Administration initially distributed the Model Minimum Inventory of Road Elements (MMIRE) in August 2007, mimicking the format of Model Minimum Uniform Crash Criteria (MMUCC). The roadway data specification distributed by FHWA comprised a catalog of data elements for the inventory of roads, along with suggested coding structures (Harrison, et al., 2016). Shortly after the initial release, there were several changes in the records of MIRE which increased the variable list to about two hundred elements. The MMIRE had turned out to be an all-inclusive inventory of roadway components for collection. Consequently, the term ‘minimum’ has been removed from the title. Thus, the model is now called MIRE instead of MMIRE. The alteration was carried out in response to remarks of the users through their reviews regarding the total number of features that "minimum" could suggest (Lefler et.al, 2010). The name signaled that the listing of elements had been declared "obligatory”. With the new title, MIRE, it is considered a model representing the nature of the listings of elements containing value-added and critical elements.

The version 1.0 of MIRE was initially released in 2010 and it includes a list of 202 elements of roadway and traffic data, along with the recommended guidelines. These guidelines are used for roadway safety analysis and similar purposes. Information included in MIRE documentation is distinguished into three general categories comprising roadway segments, roadway junctions and the descriptions of ramp/interchange. The description also includes name, definition, and the specifications and attributes that are descriptive of the data elements in each category. After the release of MIRE Version 1.0, there have been significant improvements in the collection of data elements in many states transportation agencies that comply with MRIE requirements. Because of these benefits, FHWA plans to reassess the role of MIRE Version 1.0 in meeting the requirements of roadway data users. This reassessment is also directed to determine that how the usefulness of MIRE can be further enhanced by introducing some changes or modifications in its released version (Zhou and Wang, 2015).

In 2012, it was reported by FHWA that HPMS has expanded the requirements for states departments of transportation to submit their roads Linear Reference System (LRS) including all public roads. This requirement is known as All Road Network of Linear Referenced Data or ARNOLD (Zhou and Wang, 2015). ARNOLD legislation also mandates all DOTs to collect the Fundamental Data Elements (FDE) that have been specified per the on MIRE, Appendix (A) has a full list of MIRE attributes along with FDE data elements, (Federal Highway Administration, 2014).

In the efforts of FHWA to improve the safety and quality of roadway and crash data, the Roadway Data Improvement Program (RDIP) was initiated with the purpose of helping the transportation agencies in improving the roadway data quality so that their safety initiatives can be adequately supported. The RDIP improvements are focused on areas including collection practices of data elements, data referencing, storage and maintenance along with the connection of this data with other safety data elements. This initiative of RDIP aids the database managers and other professionals of roadway and traffic management in identification, description, analysis, measurement of roadway data. Consequently, better measures can be taken to improve the quality of data by these professionals. For this, the managers considered the parameters of timeliness, consistency, accessibility, completeness, integration, and accuracy for ensuring the quality of data (Lefler et.al, 2010).

After these legislations, DOTs have started reassessing the various components of their collected databases to fulfill the fundamental elements of MIRE. The safety analysis tools and the elements proposed by MIRE are compared to provide regulation papers for the identification of common features as well as to guarantee uniformity between other databases and the listings of MIRE. These lists also incorporated the Model Minimum Uniform Crash Criteria (MMUCC), Highway Performance Monitoring System (HPMS), and the Manual on Uniform Traffic Control Devices (MUTCD), IHSDM, HSM, and Safety Analysis. Several web conferences resulted in the achievement of supplementary feedback the users of the system.

- Synchronized and linked with the Supervisory Routing Commission intended to deliver a methodological response as well as to assist as cooperation to impending consumers or users.
- Accumulated the entire feedback keen on advanced characteristics and coding elements of the MIRE.

The model inventory Roadway Elements (MIRE) is associated with MMUC data elements with minimum crash records. Moreover, it has been categorized as one of the most important existing degrees for data containing the crash elements used by both state and local authorities. The commands to improve the data system for a crash are gradually improving. A high-level website for MIRE has been recently launched facilitating authentic resources, and information (Lefler et.al, 2010).

There is a large list of elements in the MIRE that does not have all the elements required by the state department of transportation in design and operational processes; MIRE focuses on the safety perspective. The MIRE tools and elements are selected only based on the safety issues and initiatives that are concerned by the safety Analyst (Council et.al, 2007).

2.2.2 Traffic Data

Most states rely on the federally mandated HPMS to collect and maintain information on traffic levels for roadways across the state. The HPMS manual gives the overview of the HPMS system at FHWA and defines the reporting and data collecting requirements. HPMS data reports contain data on the U.S highways regarding the extent, condition, quality, operating status, performance and use of highways. The data collected by HPMS is reported to the Highway Police Information, where the FHWA office analyzes the road characteristics and evaluates the highway characteristics (Chrusciel et al, 2015).

The 23 U.S. Code 315, under Rules, Regulations, and Recommendations, authorizes the requirements of the HPMS Field Manual and places responsibility on the Secretary of Transportation for taking management related decisions that influence the transportation system. Moreover, the 23 CFR 1.5 assign authority to the Federal Highway Administrator to demand the required information to manage the Federal-aid Highway Programs. Finally, the periodic estimate of the projected investment needs is controlled by the Congress. As per Section 3 and 4 of the Government's Performance and Results Act (GPRA), FHWA is authorized to use the HPMS data in its strategic planning of investment for roadway improvements (Chrusciel et al, 2015).

2.2.3 Scope of HPMS

|The HPMS program delivers an inventory for public mileage authenticated by the Governors of the States annually for all routes of the roadways available for the public regardless of their ownership, including Federal, city, county, State, and private road like toll facilities. All State must provide data on the reporting requirement stated based the HPMS mandated requirements (Meegoda & Gao, 2014). The HPMS reports contain details of the National Highway System (NHS), which is important highways network for the nation's defense, mobility, and economy.

The HPMS also includes specific items of the data including traveling routes, lane-miles, and length required all public highways that are made accessible by the aid of the federal highway funds. These data items are specifically funded by the distribution of the highway funds based on two criteria. The data items collected for the public roads are referred as Full Extent data variables, while the other data items are collected to a fractional extent of the roadway and are called as the Sample Panel data items (Exchange, 2010).

The data of the HPMS is utilized to attain and specify the performance of the highway system in the FHWA's by the process of strategic planning. The HPMS data provides the foundational analyses that specify the Report of Conditions and Performance to Congress and is considered as the significant source of information distributed annually in the publication of the Highway Statistics and FHWA. At last the HPMS data is accessible for all transportation sector comprising governmental entities, industry and business, public and higher learning transportation institutions for research purposes (Meegoda and Gao, 2014). The HPMS data can also be utilized for measuring the performance of the transportation decision making at national, state and local levels to analyze trade-offs between different types of transportations and is categorized in the statewide and metropolitan planning process of transportation.

2.2.4 Crash Data

Model Minimum Uniform Crash Criteria (MMUCC) was initially created in effect of the States' requests on crash data improvement and standardization. Previously, there was a lack of uniform crash data reporting, which made it difficult to share and compare the data consequently creating misleading results. This situation created a need for the development of MMUCC to rectify the issue.

The purpose of MMUCC creation is to develop and provide detailed data on motor vehicle crashes. This dataset will provide the necessary information required to improve the safety conditions of highway network in all state. MMUCC data elements require to include a set of the specific characteristics defining safety conditions, along with a sound justification for each attribute. These data elements are bifurcated into four groups for each crash assessment. The groups include data on crash, vehicle, roadway and the person involved.

MMUCC states the following requirements as essential for generating highway safety improvement cases:

- All crashes that result in a damage worth $1,000 or more are required to be entered in the database.
- Crash data reporting should include all the people involved, i.e. the injured as well as the non-injured.
- It is required for every state to maintain a uniform threshold that can be implemented throughout the state.

According to the South Carolina, Traffic Collision Quick Facts (2014) following, data was reported (Table 2.1).

Table 2.1: SC Traffic Collision Data (South Carolina Traffic Collision Quick Facts, 2014).

Collision Statistics	2010	2011	2012	2013	2014	% Change 2010 - 2014	% Change 2013 - 2014
Fatal Collisions	750	768	806	719	756	0.8%	5.1%
Injury Collisions	31,152	29,756	32,325	32,854	34,062	9.3%	3.7%
Property Damage Only Collisions	75,771	71,318	75,130	79,687	84,355	11.3%	5.9%
Total Collisions	107,673	101,842	108,261	113,260	119,173	10.7%	5.2%
Fatalities	809	828	863	767	823	1.7%	7.3%
Non-fatal Injuries	48,707	46,057	50,064	50,938	53,029	8.9%	4.1%

2.3 Safety Analysis Tools

The work of the Highway Safety Manual (HSM) is a science-based practical approach which draws guesswork from the safety analysis (Hughes et.al, 2004). It provides tools to run a quantitative analysis for the safety to compute and evaluate the performances measures of the transportation such as impacts on the environment, costs of the construction and operations of the traffic. The HSM gives a technique to measure changes in the frequency of the crashes related to the cross-sectional features (Exchange, 2010). With the help of this technique, we can evaluate and compare the crash frequency with the environmental impacts and operational benefits (Hughes et.al, 2004).

2.3.1 Tools Provided by HSM

The HSM suggests techniques for constructing an efficient roadway with the safety management programs, and evaluating their effects and certain result of the construction. It also defines a procedure for identifying locations which can be beneficial in the safety perspective, diagnosing the location or site condition and identifying treatments required for safety improvements, enhancing the planning treatments and evaluating and minimizing the crash situations related to the site. Most of these methods are run to quantify the safety improvements to minimize the frequency of the crashes (Council et.al, 2007). HSM is also an efficient technique to evaluate the crash frequency and its severe effects which may affect decision-making process about the following development procedures like maintenance, operations, planning, designing of the model, and last but not the least the safety management process of safety (Bonneson, 2010).

The Crash modification factors (CMFs) contain different types of operational and geometric types of treatment supported by the scientific evidence. In the HSM sector, the CMFs was made by the high-quality literature, resulted from the regression to the mean processes. HSM also focuses on the analytical procedures to evaluate the safety effects of all decisions related to planning and executing the safety models (Hughes et.al, 2004).

2.3.2 Applications of the HSM

The HSM delivers a chance to apply safety implications to the transportation performance. The most basic plans and example of the HSM are given below:

- Identify and locate the site which is most probably affected by the crashes and minimize the severity.
- Identify and address factors related to the crashes and precautionary measure to avoid the circumstances.
- Launching economic assessment of prioritizing projects and potential improvements;
- Calculate the benefits of the crash reduction by the implemented treatments; and evaluate the consequence of the crash frequency and order of designing, planning, and policy decisions.

The HSM is utilized for the projects related to the safety questions. More of that the HSM follows the quantitative analysis of safety in the projects such as corridor evaluations to identify volume improvements and studies to the intersection to identify the different types of traffic control systems. It is also applicable for the transportation project to enhance and implement the safety procedures in their working model (Bonneson, 2010).

2.3.3 Value of implementing HSM

The HSM enables to assimilate quantitative procedures of severity and crash frequency in the project analysis, planning, evaluation and program development to enable safety measures in the projects. By implementing the tools of HSM, safety improvements will be completed. More from the legislative perspective, the HSM support at different state, local and federal levels to attain safety goals to reduce the fatalities and injuries. From the public agency point of view, it enables the safety perspectives in their methods which can be evaluated by the program and project improvement results. For this agency again provides funds for the betterment of the previous plan (Lefler et.al, 2010). To sum all above, the HSM methods are applicable for all projects of transportation - time to time - which is particularly focused on achieving goals of safety in the plans.

2.3.4 The HSM Parts

HSM is made from four parts that involve focusing on the fundamentals of the plan and the related human factors involved in this process. These parts are listed below;

a) This part provides information about the scope and purpose of the HSM, clearing the relationship in the design, planning, maintenance and operation activities. It provides tools and fundamental processes of HSM, it also ensures the background information required to enable the predictive methods, (CMFs) crash modification factors and evaluation of the further processes enlisted in other parts of the HSM (Jones et.al, 2014).

b) Safety management process of the roadways involves steps to reduce and monitor the severity and crash frequency existing in the network of the roadways. It involves procedures for improvements in identified sites, finding countermeasures selection, project prioritization, economic assessment and effective evaluation.

c) It provides the methods of predicting the crash frequency in the network of the roadways, or other sites, it also enables the safety performance functions (SPFs) for the included projects. It works by computing the determinant of crash frequency related to the roadways and traffic volume. It is also an applicable approach for the transportation issues and safety concerns.

d) Modification factor of the crash (CMFs) is used to evaluate the variations of the crash frequency resulted by the operational and geometric modifications of the site. It is applicable for the evaluation process and design where operational actions are necessary. The CMFs is also significant for the documentations of the design (Hughes et.al, 2004).

2.3.5 Assimilating the HMS in the process of project development

HSM provides the basic stages for a project from designing to the maintenance and operations of the post-construction activities. Figure 2.1 represents the relationship of the HSM with the process of project development.

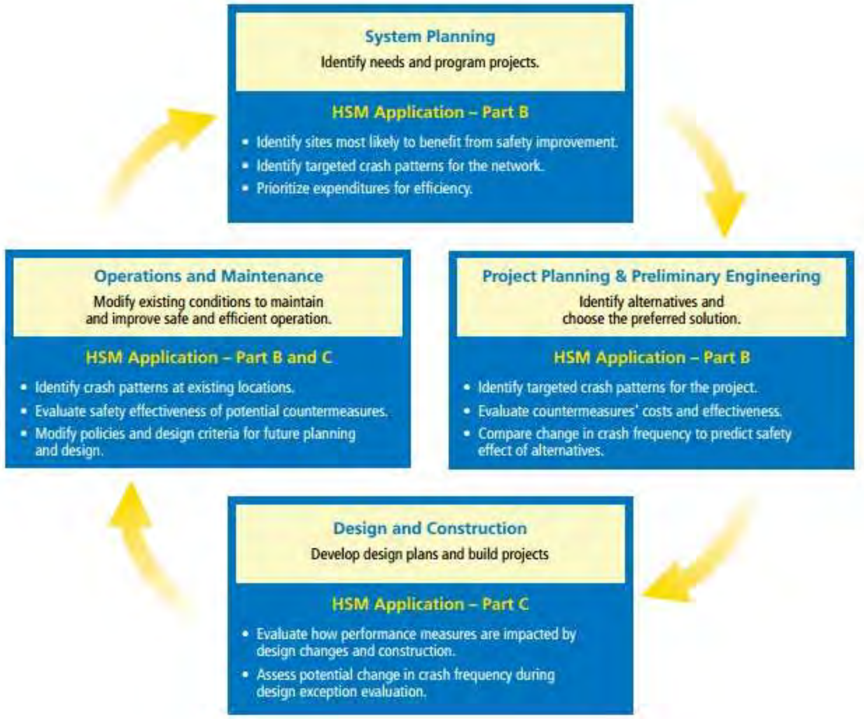

Figure 2.1: Applications of the HSM in the Project Development Process

2.4 Safety Analysis Data

2.4.1 Traffic data

Annual Average Daily Traffic (AADT) is an important parameter of the traffic used in engineering analysis and transportation planning. Every DOT provides AADT data annually to the Federal Highway Administration (FHWA) completing the criteria given by the Highway Performance Monitoring System (HPMS) (Islam, 2016). For this aim, the DOT gathers AADT data from the short-term counts and permanent count stations. In the South Carolina, primary and interstates routes are prepared by the permanent count stations (Council et.al, 2007).

To compute AADT data, one must require the complete, accurate and reliable traffic data. Some of the transportations agency noticed the missing data from traffic count stations. The missing data traffic percentage lies in a range of 10% to 60%. SCDOT gathered missing data from the recent 3-month record which can lead to flaws in data gathering, so two different approaches like Artificial Neural Network (ANN) and Support Vector Regression (SVR) are used to predict missing hourly data. The literature suggested for every functional class, the SVR method has beaten the ANN method to predict accurate data (Islam, 2016; Harrison et al., 2016). The SVR system efficiency was associated with the SCDOT's calculation practice, which showed that SVR system is efficient in estimating missing data associated with the SCDOT's method of imputation. These calculated AADT data are related to the traditional factor method applied by the SCDOT. The contrast among SVR and ANN defines that the SVR works better than ANN in the AADT evaluation for data of the roadways (Islam, 2016).

2.4.2 Roadway Inventory

The purpose is to find the effects of the width standards and flexible lane have on the operation and safety of the roadways in South Carolina (Ogle et al., 2015). Based on the background study, large data were required to measure the operational and safety impacts linked with the width of a lane. After analyzing the data available in RIM and enterprises system, the finder team embarked on field data collection to attain shoulder widths, lane widths, the presence of light and side slopes, etc.

Most of the cross-sectional elements gathered in the RIMS folder were based on segmentation of the roadway which could be upgraded for growth and success. It was obtained that some of the factors were not linked in the RIMS segmentation process, causing the non-homogeneous segments in the observational sample (Ogle et al., 2015). If HSM technique is considered while construction, the roadways segmentation process will be very accurate for the safety analysis. Knowledge of HSM attributes enables the improvement and safety features of the roadways.

Eventually, SCDOT concluded recent research project in constructing best roadways to support the upcoming safety challenges. This process shields new technology perspectives, detail needed for every element and database structure required to build improvements and keeping the structure updated (Ogle, Sarasua & Davis, 2015).

2.4.3 The Crash Data

Some of the agencies have concluded data evaluation and completion process to attain safety planning which includes the Crash Data Improvement Program (CDIP) and the Roadway Data Improvement Program (RDIP). The CDIP is used to assist managers in the state about the crash database, identifying traffic safety, measuring and defining the features of the data quality with the crash database. The CDIP focus of the quality improvement like completeness, accuracy, addition, and availability of crash data (Boodlal, Emery & Souleyrette 2010). It provides the way to States to enhance the assessments and measures related to the features of the crash data.

CHAPTER THREE

METHODOLOGIES

The SCDOT collects a large amount of data for purposes ranging from scientific decision making to public reporting obligations. Meaningful data collection and maintenance can support objectives such as policy making, resource allocation, and operational decisions within the SCDOT. These objectives can be accomplished by the methodology described in this chapter in the following three phases also shown in Figure 3.1. In this work, different methodologies and tools have been developed for assessing the network data assets, and improving safety data management process. The assessment process includes three major phases (Spy Pond Partners, 2015).

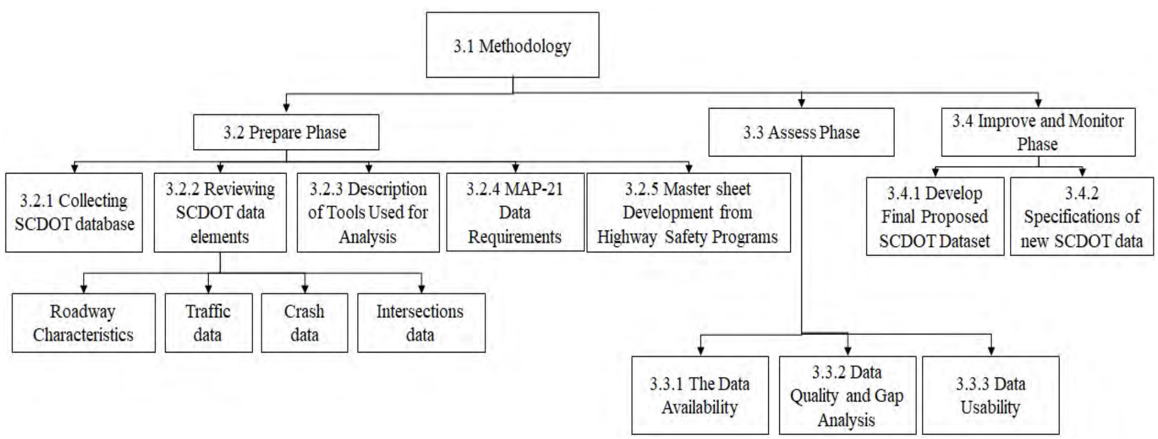

Figure 3.1: Phases and steps were taken towards achieving the objectives of this research.

In the first phase (i.e. prepare), the federally mandated reporting systems for roadway safety are identified/reviewed and a description of the SCDOT data inventories is also provided. This helps to identifiey which data components to include and to undertake under recent roadway safety legislations. For the second phase (i.e. assess), the research team used/developed tools to identify relative strength and weakness in the selected data sets by understanding gaps in the current capabilities and the designed future state using two types of assessments. The first type focuses on a data value in the frame of specific business function or data policy, while the second type focuses on assessing data management capabilities to either whole agency level or on a data level. In the final phase, a prioritized plan and recommendations for data improvement in SCDOT were suggested considering the agency priorities in collecting data. Figure 3.2 summarizes three phases of the data improvement and management.

Figure 3.2: Data assessment process - source: (Spy Pond Partners, 2015)

3.1 *Phase 1* Prepare Data for Assessment

In this section, the data preparation required for assessment of SCDOT performance goals are described.

3.1.1 Accessing SCDOT Databases

Four major data sources maintained by SCDOT were used in this study including RIMS, Highway Crashes, AADT tables, and e-TEAMS (GIS/Mapping, last accessed June 2017). The RIMS database was selected as the main source as it provides most of the roadway identification and cross section attributes. The AADT data is collected by 134 Automatic Traffic Recorders (ART) stations statewide (SCDOT, Traffic Counts). Crash data is obtained for 16 jurisdictions from the Traffic Collision Report Form (TR-310) reported annually by SCDOT. The crash data provides details including but not limited to crash location, sequence of events leading to crash, units involved, driver and occupant information ant etc. Finally, the e-TEAMS represents part of intersections data in SC which was also included in this analysis.

3.1.2 Reviewing SCDOT Data

The four aforementioned datasets are described in more details in the following subsections.

3.1.2.1 Roadway Inventory

The attributes of roadway segments in South Carolina are available in Roadway Inventory Management System (RIMS) data set, maintained by the PMG Software

Professionals (PMGPro). For each roadway, a unique Linear Referencing System (LRS) ID is assigned along with milepost which is used to assign the attributes to roadway segments. RIMS roadway inventory contains 75195 records representing different attributes of 37,000 routes that has a unique ID known as Route_LRS. Rout_LRS has twelve digits (e.g., "02010002000E"). The first two digits represent the county number followed by two digits for the route type and. Each route can be divided into smaller segments based on desired attributes. A total length of 41281.87 miles of South Carolina roads is covered in this data, not including the local routes.

3.1.2.2 Traffic Volume Data

The average annual daily traffic (AADT) information for all roadway segments (more than 12,000 count stations) in South Carolina is obtained from the SCDOT. The AADT information for 2011 and 2014 was provided in two formats. In the first one, the information from these data was already geospatially linked to RIMS data using the LRS and given under the attribute table of the shapefile. In a second way, the information of the AADT was provided in separate text files. AADT data acquired from these two files were compared to see if they are identical and examined for missing records. No discrepancy in the two datasets was observed for all roadway segments (45140) during the two years of analysis. SCDOT uses actual counts and estimations based on similar road conditions. These counts are sometimes slightly changed to adapt to seasonal variations.

3.1.2.3 Crash Data

The crash data for the years of 2007 and 2015 was collected from SCDOT. South Carolina Traffic Collision Fact Book provides a full list of the crash elements along with their domain codes and summary statistics. Codes translation were taken the Uniform Traffic Collision Report Form (TR-310). Crash Reporting Threshold (CRT) in South Carolina is defined as at least1000$ damage or fatal/injury crash (RT-310 manual). Crash data has three components including location file, unit file and occupant file. Location file contains information related to crash lactations such as county, day, time, the latitude and longitude coordinates, whether condition, etc. Unit file contains the information about all units involved in each collision such as unit type and number, driver name, license number… etc. Occupant file includes information about occupants in each unit including sex, race, date of birth, seat location, restraint equipment used airbag information, whether occupants being ejected including the driver. These three files are related by accident number and unit number.

3.1.2.4 Intersections data

The e-TEAMS dataset includes 11 data elements for 4012 intersections. such as city name, the number of leg, names of approaches, and the presence of traffic signals. Very limited information was found on this database.

3.1.3 Description of Tools Used for Analysis

Several tools were utilized to find the summary statistics of each data element in four aforementioned datasets including domain, data range values, the percentage of completions, and the frequency distribution. Based on that, four data dictionaries (or metadata) were created to summarize these statistical measures for each data inventory reviewed in this study. The dictionaries also list the information about the codes each attribute can have. More details are provided in the next chapter. To serve that purpose, a tool was developed in Microsoft Office Access 365 forms which fully lists of the specification collected about these elements (exhibited in Figure 3.3). Some of these tools are briefly summarized herein:

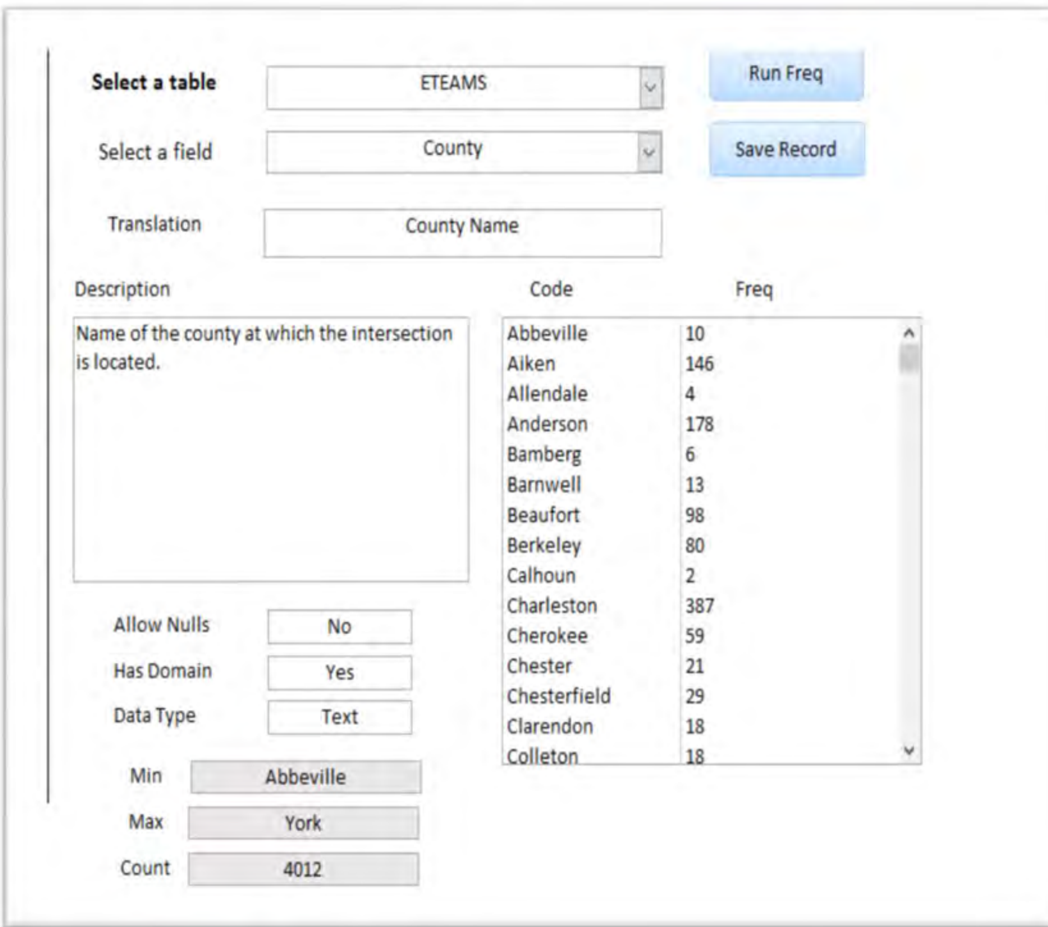

Figure 3.3: Statistical description and the specification of each element in the databases.

3.1.4 MAP-21 Mandatory Data Requirements

Towards achieving MAP-21 requirements, the SCDOT has released a strategic statewide transportation improvement program targeting all funded projects including safety known as Statewide Transportation Improvement Plan (STIP). One main goal of STIP to assure that the SCDOT accommodates with the MAP-21 legislations, which urge the States to have a Safety Data System that can be used to perform analyses supporting their strategic and performance-based safety goals for their Highway Safety Improvement Program (HSIP). As part of this process, the research team reviewed three federal mandates reporting components on roadway inventories, traffic volumes, crashes, and intersection data. This includes two safety programs MIRE, HPMS, and one safety tool HSM data components, where on which most DOT's depend in generating data and data needs. This is necessary to advance the capabilities of SCDOT in safety data collection, integration, and analysis to support program planning and performance management. Therefore, the next section addresses the development of an integrated master sheet for all the data elements required by these safety programs/tools. The creation of such comprehensive data product would allow improving the quality of the agency's current data product in terms of its timeliness, accuracy, completeness, uniformity, integration, and accessibility.

3.1.5 Master sheet Development from Highway Safety Programs/Tools.

One objective of this work is to evaluate the current practice of collecting safety data (including crash, roadway, and traffic data), investigate gaps in current SCDOT four databases mentioned earlier from the goal standards, and suggest improvements for the future safety-related data collection. As part of the modified HSIP to accommodate with MAP-21 requirements, all state roadways, traffic, and crash data must be linked or combined by the virtue of having common data elements. These data should be linked to the code State's safety elements such as license, vehicle, citation, emergency medical of injury surveillance services (23 U.S.C. 148 (c)(2)(A)(iii)). To achieve this purpose, fields from two safety highway data programs including MIRE, HPMS, and one advanced safety program tool namely HSM were combined into one transportation system information master sheet. This involves extracting the fields of the database main structure (MIRE in this case), collecting data on all fields required by HPMS and HSM, and integrating all fields from the three transportation system variables. Combining these three main types of data makes it possible for us to track safety data, analyze roadway features, and perform other useful analysis. During the courses of this project, the research team will adopt this metric, adding to it columns from other necessary data program requirements. This set of information will help SCDOT select the most effective treatment to the recent data collection practices which eventually leads to reduce the fatalities and injuries in accidents, and better manage the newly collected data for the State Highway system and other roadways in South Carolina.

The attributes in the master sheet are prioritized based on the potential data desired by each safety data program and tool. For example, MIRE, HPMS, and HSM data list are structured into two components, consisting the core (primary) components of the data defined as the skeleton of the safety data. This part of the data includes elements that as defined as the Fundamental (FED) by MIRE data list, required for Full Extent (FE) in

HPMS program, and Required (R) HSM tool. Some examples of these elements are road segments (e.g., County Name, Segment Identifier, Segment Length, Route Signing, etc.) and road nodes (e.g., intersection and junctions, crosswalks, pedestrians, and overpass, etc.). The other part of the data structure includes optional or secondary components such as Truck Speed Limit, Mean Speed, Railroad Crossing Number, and Driveway density, etc. The relationship between the primary and the secondary components is developed based on the importance given to the attribute in the advanced safety management programs and tools. The attributes required by each selected safety program along with their level of importance are compiled in a one comprehensive master sheet. Table 3.1 shows different categories by which different attributes are classified for each data program/tool in the master sheet.

Table 3.1 Different categories by which different attributes are classified for each data program/tool.

Attributes	MIRE		HPMS	Safety Analyst	HSM/IHSDM	**SCDOT State/Local
	FED*	Priority				
Name	Yes/No	Critical	*FE	*R/O	*R/O	Y/N

*FED: is Fundamental; FE: is Full Extent; R: is Required, and O: Optional data element for MIRE, HPMS, and HSM safety programs and tool, respectively.

** Determines whether this attribute is collected for the entire state or just for samples (Y) or not (N) of the SC roads.

3.2 *Phase 2* SCDOT Data Assessment

In this phase, the assessment practice is performed by comparing different collated elements with corresponding safety standards. This assessment helps to investigate data users and manager perspective and to determine whether the data collected is adding value to the agency business practices. The potential assessment elements are listed below which will be evaluated based on data analyzed in the prepare phase.

3.2.1 Data Availability

In this step, the SCDOT available data is compared to the MIRE, HPMS, and HSM data requirement. The priority in this analysis was to specify the primary data elements (i.e., FED, FE, and R in MIRE, HPMS, and HSM, respectively) required by each safety program and to make sure that they are collected by the SCDOT. This analysis also includes looking to the secondary (not primary) data elements that are not critical for the safety programs and collated by SCDOT. The current SCDOT roadway and intersection characteristics, traffic, and crash data databases mentioned previously were reviewed to identify whether each element is a primary attribute in each of MIRE, HPMS, and HSM. Based on this mapping technique, four instances were recognized in the master sheet that reflects various conditions of the data elements collection practiced by the SCDOT, when they are compared to the corresponding data elements in MIRE, HPMS, and HSM. Four color codes have been assigned for different elements based on these criteria and explained in Table 3.2. It is important to emphasize here that data elements colored with green and red are very crucial for the implantation of safety management program because they represent the minimum data elements that FHWA and HSM encourage all DOTs to maintain for all state roadway systems. The green color identifies the state of the art of the data elements collated by the SCDOT under the current safety plan, while the red color represents the primary data elements required by each FHWA's safety programs and HSM tool and not collected in the SCDOT as described in Table 3.2.

Table 3.2 Colour Coding approach for assigning different SCDOT data elements.

Codes	Description
	HPMS FE, MIRE FED, HSM R - Collected by SCDOT
	HPMS FE, MIRE FED, HSM R - Not Collected by SCDOT
	Not HPMS FE, MIRE FED, HSM O - Collected by SCDOT
	Not HPMS FE - Not Collected by SCDOT

With the aid of the SCDOT, we also obtained more information on whether the data elements are being collected state-wide or for samples of roadway sections (see the last column of Table 1). The evaluation of data elements on sampled roadway sections was also conducted to identify the potential supplemental databases that may contain useful information on MIRE, HPMS, and HSM lists. The coverage of the local data elements to include all state roads was also examined as an important step towards achieving an acceptance level of implantation for the safety management system on the state level. Lastly, the inventory form which each SCDOT data element collected was also identified in this master sheet which is an essential step to evaluate if the emerging technique of many available data inventories can assemble more required information for MIRE, HPMS, and HSM data elements.

3.2.2 Data Quality

This step addresses whether the currently collected data are good to meet the SCDOT safety requirements. This will be accomplished by first, the issues with the reviewed SCDOT inventories are discussed based on different analysis tools such as ArcGIS, and statistical measures for each data element in the inventories such as range values, data type, missing or out of domain data, and data frequencies. Based on that, various primary levels of data quality performance matrices of concern to the SCDOT are evaluated including timeliness, currency, accuracy, uniformity, integration, accessibility, and completeness. These performance matrices represent a critical step towards achieving an acceptable level of implementation of MIRE, HPMS, and HSM variables, converting them into management information system, and suggesting additional revisions action based on these performance measures.

3.2.2.1 Performance Measures

The following performance measures proposed in the National Highway Traffic Safety Administration (NHTSA) report for roadway data accuracy are used to evaluate the performance of the SCDOT databases. On limitation is that some of the performance measures such Timelines is not estimated because its dependency on time span after completing the data collection till it is fully uploaded on the server and become available for use. Table 3.3 summarizes the model performance distributions for data system and attributes.

Table 3.3 Number of performance measure metrics used in this evaluation.

Data system	Performance Attributes			
	Accuracy	Completeness	Uniformity	Total
Crashes	1	4	1	6
Roadways	1	4	1	6
Total	2	8	2	12

3.2.2.2 Performance Attributes (PA)

1. Accuracy: it reflects the number of errors in information entered the data inventory. The Errors are the incorrect recording value in each data element compared to the code in safety manual and do not mean missing information. Some examples on deducting errors in the records such as; a) Not having a legitimate coding, b) Not matching with external source of information, and c) having duplicate records for the same event being reported.

2. Completeness: It measures both internal and externa aspects for the database being evaluated. The external component reflects the portion of the applicable events in the state for which the data is collected and entered the database. This aspect is more challenging because of the problems related the ownerships and fund availability. On the other hand, the internal aspect measures wither or not the databases contain precis information (i.e., the number of missing records (blank) in each data element).

3. Uniformity: it reflects the consistency of the files and records in the databases measured against some independent standards (i.e., coding consistency with MIRE for roadways and traffic, and MMUCC for crash databases). For more detailed information on all types of measuring accessibility, readers are referred to the National Highway Traffic Safety Administration (NHTSA) report for roadway data accuracy. Table 3.4 explains different metrics for test roadway data quality

Table 3.4 Roadway database mode performance measures

Roadway Database Accuracy	Roadway Database Completeness	Roadway Database Uniformity
R-A-1: The percentage of all road segment records with no errors in critical data elements.	R-C-1: The Percentage of roads with no missing critical data elements.	R-U-1: The number of MIRE compliant data elements entered to the database or obtained via linkage to other data bases.
	R-C-2: The percentage of public road miles or jurisdictions identified on the Stat's based map or roadway inventory file.	
	R-C-3: The percentage of unknowns or blanks in critical data elements for which unknown is not an acceptable value.	
	R-C-4: The percentage of total roadway segments that include location coordinates, using measurement frames such as a GIS basemap.	

The results of the above performance measure analysis are given weights that represent the maturity level criteria to assess each element in the SCDOT databases. The researchers are based their element weighting system on the following four points element level scale that described in Table 9. This weighting measure is based on the percentage of each matric in the this table, where each element maturity level was translated to a numeric score and weighted level (Table 3.5). This process allowed for creating as overall average measure in each level of that category.

Table 3.5 Rating of weighted point system for each element based on performance measures.

Description	Point Value	Percentage
Poor	1	0-40
Fair	2	41-60
Good	3	61-80
Very Good	4	81-100

This work also analyzed gaps in the SCDOT data by focusing on the relationships between recent safety planning elements and its related projects, current tools put by the SCDOT, and future state goals. Gap analysis is built based on the previous data inventories collected by the SCDOT through binding together sub-elements of large data sets and introduces new concepts yielded from safety planning. This step in the collected data helps planners, and SCDOT to achieve their safety performance goals put by activities, which could be used to expand knowledge of the data usage.

3.3 *Phase 3* The SCDOT Data Improvement

In the last phase, the potentials of using existing and emerging data collection technologies such as (LiDAR) for SCDOT are evaluated by comparing their collected data elements to the data collected at Utah DOT (UDOT). The UDOT uses semi to fully automated LiDAR system for data collection. In the fully process both data collections and analysis are done automatically by using imaging and sensor technologies and special programs designed for this purposes without operator interference. To accomplish this step, various roadway and traffic inventories available at UDOT website were reviewed to see if the elements listed in the master sheet are being collected by the UDOT. Also, the collection method (i.e., automatic or manual) was reported and intergrade to the master sheet. Based on these results recommendations for implementation plans have been suggested for improving the SCDOT data collection practices and management.

For next part of this phase, a feedback was received from other researchers who had worked on manually safety data collection from satellite imagery using HSM tool in South Carolina. Some of these elements are also required by MIRE and HPMS data programs on a State level such as elements of the roadway and intersection inventories (e.g., lane width, median, fixed objects, type of interactions, lighting conditions, and so on). Researchers were asked to rank the data collection experience using similar rank defined earlier. This helped us confirming the critical data elements that are not available for state DOT, necessary for safety decision, and difficult to collect at the same time. After the evaluation is weighted on a scale from 1 to 5 with 1 being very easy, 2 is easy, and 5 is very difficult.

3.3.1 Develop Final Proposed SCDOT Dataset:

The final output of this step includes the results of rewiring RIMS, AADT, Crash, and e-TEAMS data currently maintained by SCDOT as well as a prioritized listing of additional data elements to be collected based on gap analysis.

A prerequisite for the development of specifications for a database is to define the focus, content, scope, and access to other agencies and private-sector data sources. The perspectives of different safety assessments requirements will be gathered by comparing the current SCDOT data with the developed master sheet compiled based on safety programs/tools. Based on the analysis of the user preferences, a database specification will be proposed. The specification will consist of overall structure in the schema or other global definition of the database, as well as a data dictionary.

CHAPTER FOUR

ANALYSIS AND RESULTS

In Chapter 3, the analysis in this project is mainly divided into three phases that will be addressed accordingly in this chapter.

4.1 *Phase 1* Prepare and Review Data for Assessment

This phase sets up the stages to perform various analyses necessary to achieve the objectives of this research. It also describes the collection of the analyzed databases and reveals the current and potential issues in the roadway, traffic, and crash data characteristics reviewed in the inventories, along with the data cleaning requirements. At the end of this phase, a summary list with data issues will be provided in a preparation for assessing the quality of the safety data.

4.1.1 Roadway Characteristics and Traffic Data:

States usually maintain multiple inventories in their databases, and each inventory represents some part of the state entire roadway system population. The more inventories the state uses to keep similar roadway data, the more likely the stored fields are either overlooked, overlapped, or missed. Like other states, the SCDOT uses RIMS data management system to maintain the roadway inventory for all interstate, primary and non-primary roadways. The road way inventory is linked to state's roads basemap (GIS map) using the linear referencing system (LRS). The data dictionary created from RIMS roadway inventory has 54 data elements with 75195 data records spatially referenced using the LRS.

To measure safety performance, traffic and crash information are always linked to the roadway characteristics through attributing this information to a road “segment”, as used by the FAHW’s safety programs, for finding different correlations between data. Since roadway characteristic files consist large number of segments, there are usually errors with associating these data to right segment location especially when many data variables are collated (i.e., smaller segments are defined). South Carolina collects and maintains their roadways characteristics as part of RIMS data inventories including interstates, primary, and non-primary roads across the State, all known as federal-aid roadways.

As mentioned earlier the length of roadway segments in RIMS data range from few feet to 16.5 miles with mean of 0.55 miles for the 33970 segments. All segments are georeferenced to the corresponding polylines in the shapefiles (i.e., no 0.00 length was found in the data) and that about 70% of the segments have a length <0.78 miles which indicates the variability in descripting different information of South Carolina road sections. However, some coding and georeferencing issues were uncovered in the data and many were related to the data entry. Some of these issues are identified by ArcGIS or Access software and some were purely identified visually. Following are some major issues observed in the road data inventory.

(a) Issues with shorter roadway segments: Figure 4.1 gives the spatial locations and the distribution of different road segment lengths stored in the GIS shapefile of RIMS roadway inventory. As can be noticed form this figure, most segments have lengths biased towards smaller vales with around 50% shorter than 0.18

miles and 10% less than 0.05 miles. The issue with shorter segment lengths can have a great effect on crash rates, where shorter lengths tend to have higher crash rates. State-wide, it is observed that about 24% of the crashes in 2015 occurred on roadway segments with <0.19 miles in length. Although, shorter segments indicate variations in roadway characteristics, this could cause to coding and sensitivity errors in the SCDOT data.

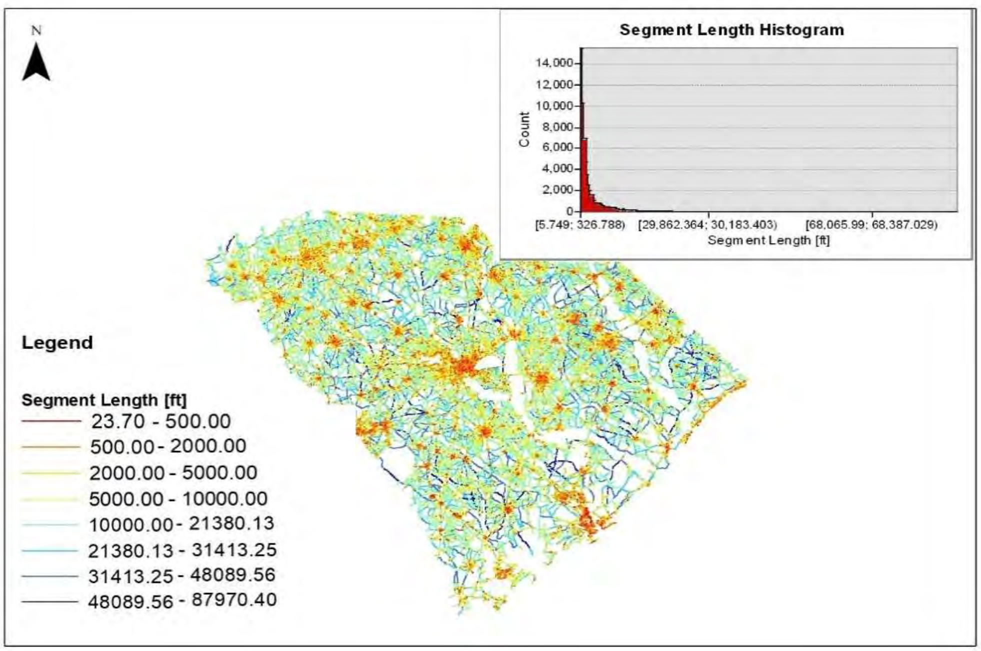

Figure 4.1: Locations and the histogram of different road segment lengths stored in GIS shapefile of RIMS roadway inventory.

(b) The directional representation for route segments is not accurate for some interstates where the routes are represented for only one direction in the inventory and not centered. An example is shown in Figure 4.2.

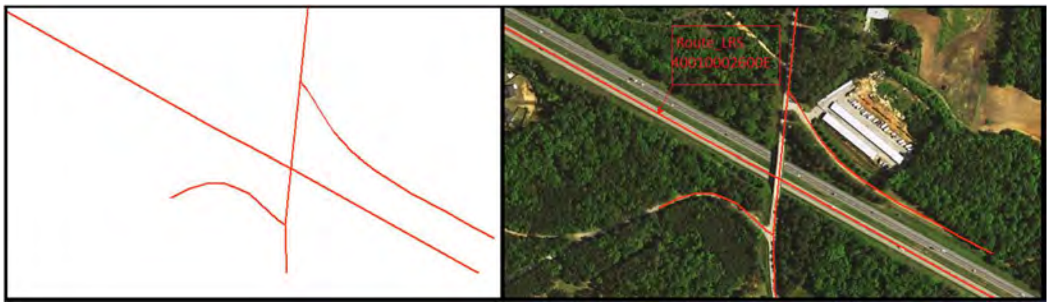

Figure 4.2: Directional representation for route segments.

(c) At primary and non-primary locations, some routes have been isolated from the main network. An example is shown in Figure 4.3.

Figure 4.3: Broken or Unconnected route segments.

(d) When the continuation of a route is broken due to another route, the segmentation sometimes miss represents the actual road segment as shown in Figure 4.4.

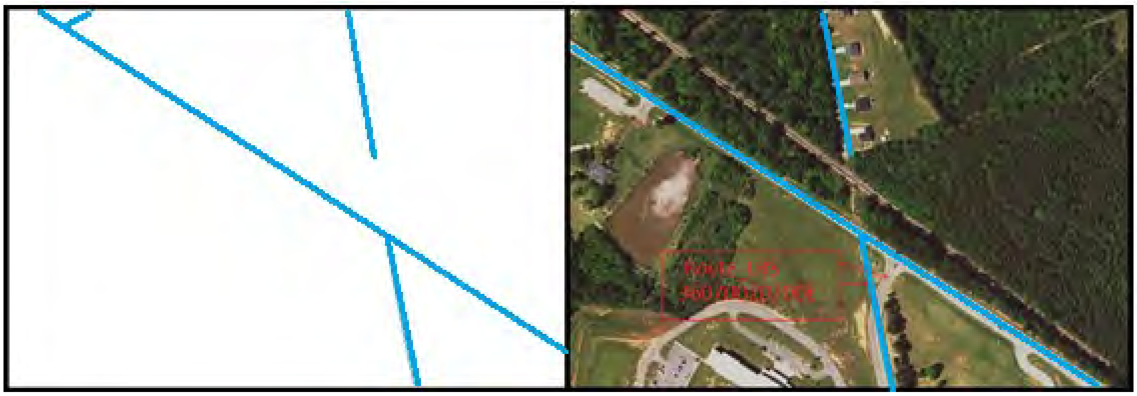

Figure 4.4: Miss-representation of the actual road segments.

Given that a considerable amount of time was spent on monitoring the routes with LRS in GIS, this referencing system could create discrepancy between basemap and roadway inventories as the basemap could have certain roads and the roadway inventories may contain more or less data than the basemap segments. These problems need to be identified and corrected for use in safety analysis. The improvement can be done in GIS coding and processing the network.

4.1.2 Intersection Data

The review of e-TEAMS, which contain State's intersections data both signalized and non-signalized intersections, revealed that there is a total of 4012 intersections records in this data inventories. This approximately represents only 16% of the State's intersections data when compared to RIMS data inventory. The e-TEAMS data inventory has many coding errors and missing entries, with unknown reasons. Below (Table 4.1) is some information about the filed names in this data along with some coding problems. The information maintained in this database is very limited which mismatches the MIRE Version 1.0 coding and data elements requirements. This implies that e-TEAMS data has very limited information suitable for safety analysis based on the functional classes.

Table 4.1: Some examples of the e-TEAMS data issues

Field Name	Data Inventory	Type of Error
City Name	e-TEAMS	Missing data
Major and Minor Road Names	e-TEAMS	Blank Information

4.1.3 Crash Data

Three components of crash data reports are analyzed counting for Location, Unit, and Occupants databases. The Location data inventory was compared for the years of 2007 and 2015 to obtain a final crash that were spatially located. Based on that, it was observed that, for 2007, there were 112,067 crashes and 147,023 crashes for 2015 with 31% relative increase. Among these locations there are 13569 and 15575 not spatially referenced in 2007 and 2015 which represents 13% and 11% of the total crashes reported for these two years, respectively. Some of the issues were identified in the data as follows:

1. More than 30% of the crashes were spatially located in Greenville, Charleston, and Richland Counties with approximately 10% share for each County. These rates

were similar during 2007 and 2015, and could indicate the performance in applying safety measures on the State's highways.

2. Because of using both the linear referencing and the GPS systems to spatially locate each crash along each route, it was impossible to validate the location of each crash with higher accuracy. The reported crash information was completely collected by the law enforcement officers based on crash report form; therefore, our findings found that the inaccuracy in redefining the crash locations was within -/+100 ft. (Based on the current GPS devises used in the data collections). This could create biased safety analysis results as these reported locations are not realistic.
3. The accident databases were found to have many errors, meaningless information, and unused fields. Table 4.2 illustrates some of these data issues found while reviewing the data inventories. The full data assessment for all elements is provided in the next sections.

Table 4.2: Some examples on crash data issues

Field Name	Data Inventory	Type of error
Lane ramp direction (BDI)	Location	Missing entry
Mile/ Grip Reference Indenter (RPI)	Location	No Data
Action Prior to Impact (API)	Unit	No Data
ATR2	Unit	Unknown
Dr-Ped-Name (NAM)	Unit	Unknown Entries

4.2 *Phase 2* SCDOT Data Assessment

The tools developed for analyzing statistical information of SCDOT data and the master sheet derived from safety programs/tools are employed to assess SCDOT roadway, traffic, and crash data inventories. The formulation of these tools and the master sheet are discussed in details in the previous chapter, sections 3.1.3 and 3.1.4. Based on this analysis, below are the results of different parts of that assessment.

4.2.1 Data Availability

4.2.1.1 Roadway, Traffic, and Intersection data inventories

Table 4.3 demonstrates the MIRE elements available in the SCDOT databases including the roadway, traffic, and intersection databases. The following points summarize the results of the assessed databases:

1. This table shows that the assessed SCDOT databases contain only about 40% of the total MIRE list.
2. The databases have a fair amount of roadway segment descriptors and lacks most alignment and junction descriptors.
3. The majority of the databases data have information on segment location/linkage variables and segment cross-section with 14 elements collected out of 18 for both subcategories.
4. The SCDOT data inventories have all roadway classification elements listed in MIRE (4 out of 4 elements), such as rural/urban designation, functional class, and federal aid.

5. Fewer information on segment traffic flow data, operations, and control data subcategories existed in the SCDOT traffic databases focusing only on the magnitude of the traffic volumes and type of roadway operations (i.e., one/two-way).
6. None of the databases contained information on traffic characteristics like directional and K-factors, and percent trucks in the traffic flow subcategory. Whereas for traffic operations/controls subcategory, nearly all databases lack information about speed limits, 85th percentiles speed, school zones indicators, on street parking presences, etc.
7. For roadway alignment and roadway junction categories, data for horizontal curves (e.g., radius, superelevation, and length of curves) and similarity for vertical alignment grades (e.g., percentage of grades and identifiers) are not provided in the databases surveyed in this study.

Table 4.3: the total number of MIRE data elements maintained by SCDOT data inventories classified by each subcategory.

MIRE Data Subcategories	Total elements in a subcategory	Elements for MIRE in SCDOT Databases by Category		Elements for MIRE Not in SCDOT Databases by Category	
I. ROADWAY SEGMENT DESCRIPTORS (Total number of MIRE Elements = 106)					
I.a. Segment location/linkage variables	18	15	83.33	3	16.67
I.b. Segment roadway classification	4	4	100.00	0	0.00
I.c. Segment cross-section	39	18	46.15	21	53.85
I.d. Segment roadside descriptors	13	0	0.00	13	100.00
I.e. Other segment descriptors	4	4	100.00	0	0.00
1.f. Segment traffic flow data	12	9	75.00	3	25.00

I.g. Segment traffic operations/control data	15	4	26.67	11	73.33
I.h. Other supplemental descriptors	1	1	100.00	0	0.00
II. ROADWAY ALIGNMENT DESCRIPTORS (Total number of MIRE Elements = 13)					
I.a. Horizontal curve data	8.00	2	25.00	6	75.00
I.b. Vertical grade data	5.00	2	40.00	3	60.00
III. ROADWAY JUNCTION DESCRIPTORS (Total number of MIRE Elements = 83)					
III.a. At-Grade intersection/junctions	58.00	7	12.07	51	87.93
III.b. Interchange and ramp descriptors	25.00	14	56.00	11	44.00
Total Number of Elements	202.00	80	39.60	122	60.40

Table 4.4 summarizes the MIRE FDE data elements existed in the evaluated SCDOT data inventories. The SCDOT databases have about 88% of the MIRE FDE data elements. All the elements of roadway segment descriptors such as Segment location/linkage variables and Segment roadway classification are available in the SCDOT data inventories. However, The State has only 50% of the MIRE FED on the roadway junctions in their databases including interchanges, intersections, and ramps. The uncollected MIRE FED data attributes contain information about identifiers, Ramp length, traffic data, Road types at the beginning and end of Ramp terminals. Most of these elements are required for safety analysis according the HSM data list.

Table 4.4: Number of MIRE FDE data elements maintained by SCDOT data inventories classified by each subcategory.

MIRE Data Subcategories	Total FDE elements in a subcategory	Elements for MIRE FDE in SCDOT Databases by Category		Elements for MIRE FDE Not in SCDOT Databases by Category	
		Number	Percentage	Number	Percentage
I. ROADWAY SEGMENT DESCRIPTORS (Total number of MIRE Elements = 106)					
I.a. Segment location/linkage variables	8	8	100.00	0	0.00
I.b. Segment roadway classification	4	4	100.00	0	0.00
I.c. Segment cross-section	3	3	100.00	0	0.00
I.d. Segment roadside descriptors	0	0	0.00	0	0.00
I.e. Other segment descriptors	0	0	0.00	0	0.00
1.f. Segment traffic flow data	2	2	100.00	0	0.00
I.g. Segment traffic operations/control data	1	1	100.00	0	0.00
I.h. Other supplemental descriptors	0	0	0.00	0	0.00
II. ROADWAY ALIGNMENT DESCRIPTORS (Total number of MIRE Elements = 13)					
I.a. Horizontal curve data	0	0	0.00	0	0.00
I.b. Vertical grade data	0	0	0.00	0	0.00
III. ROADWAY JUNCTION DESCRIPTORS (Total number of MIRE Elements = 83)					
III.a. At-Grade intersection/junctions	6	3	50.00	3	50.00
III.b. Interchange and ramp descriptors	9	8	88.89	1	11.11
Total Number of Elements	33	29	87.88	4	12.12

Table 4.5 lists the MIRE Version 1.0 data elements required by HPMS program and found in the SCDOT data inventories. The research team observed that the SCDOT databases contain about 92.59% (20 of 27) of the HPMS Full Extent dataset, ranging from maximum of 11 data items for Segment location/linkage variables to a minimum of 2 data items for Segment traffic operations/control data. Of 5 HPMS FE data items on Segment cross-section, only 2 data items were not collected including High Occupancy Vehicles

(HOV) Lane Presence/Types, and HOV Lanes. The HPMS Sample dataset contains 20 data items of 20 in the MIRE Version 1.0, extending from 10 data items for Segment cross-section to a minimum of 2 for Segment traffic operations/control data and Segment traffic flow data related data items. The above discussion indicates that the SCDOT mostly fulfills HPMS reporting requirements.

Table 4.5: Number of HPMS data elements in MIRE Version 1.0 and surveyed in SCDOT data inventories classified by each subcategory.

MIRE Data Subcategories	Total elements in a subcategory		Elements for HPMS in SCDOT Databases by Category				Elements for HPMS NOT in SCDOT Databases by Category			
			FE		S		FE		S	
	FE *	S*	N*	P*	N	P	N	P	N	P
I. ROADWAY SEGMENT DESCRIPTORS (Total number of MIRE Elements = 106)										
I.a. Segment location/linkage variables	11	0	11	100	0	0	0	0	0	0
I.b. Segment roadway classification	4	0	4	100	0	0	0	0	0	0
I.c. Segment cross-section	5	10	3	60	10	100	2	40	0	0
I.d. Segment roadside descriptors	0	0	0	0	0	0	0	0	0	0
I.e. Other segment descriptors	0	4	0	0	4	100	0	0	0	0
1.f. Segment traffic flow data	5	2	5	100	2	100	0	0	0	0
I.g. Segment traffic operations/control data	2	2	2	100	2	100	0	0	0	0
I.h. Other supplemental descriptors	0	0	0	0	0	0	0	0	0	0
II. ROADWAY ALIGNMENT DESCRIPTORS (Total number of MIRE Elements = 13)										
II.a. Horizontal curve data	0	1	0	0	1	100	0	0	0	0
II.b. Vertical grade data	0	1	0	0	1	100	0	0	0	0
III. ROADWAY JUNCTION DESCRIPTORS (Total number of MIRE Elements = 83)										
III.a. At-Grade intersection/junctions	0	0	0	0	0	0	0	0	0	0
III.b. Interchange and ramp descriptors	0	0	0	0	0	0	0	0	0	0
Total Number of Elements	27	20	25	92.59	20	100	2	7.41	0	0

* FE= full extent, S= sample, N= number, and P=percentage.

Table 4.6 reports the Highway Safety Model (HSM) data surveyed in the data collections process practiced by SCDOT. Based on the results of this analysis, the SCDOT data inventories seem to have the least number of HSM R data elements with 42.74%, and 0.00% for HSM O data elements, respectively (Table 4.6). The required HSM data elements generally focus on the Segment cross-section, At-Grade intersection/junctions, and on Interchange and description and descripts related data elements where it has 39, 28, and 23 elements of the total MIRE elements (202). The attributes in these three subcategories represent about 45% of the MIRE data list and are critical/required for roadway safety assessment based on HSM. It was observed that all HSM R data elements for Segment location/linkage variables (7) and Segment roadway classification (2) were included in the SCDOT data inventories. The above discussion suggests that the SCDOT's implementation of HSM in safety assessment of the State's roadway is still in the preliminary stages.

Table 4.6: Number of Required and Optional HSM data elements in MIRE Version 1.0 and surveyed in SCDOT data inventories classified by each subcategory.

MIRE Data Subcategories	Total elements in a subcategory		Elements for HSM in SCDOT Databases by Category				Elements for HSM NOT in SCDOT Databases by Category			
			R		O		R		O	
	R*	O*	N*	P*	N	P	N	P	N	P
I. ROADWAY SEGMENT DESCRIPTORS (Total number of MIRE Elements = 106)										
I.a. Segment location/linkage variables	7	0	7	100	0	0	0	0	0	0
I.b. Segment roadway classification	2	0	2	100	0	0	0	0	0	0
I.c. Segment cross-section	24	0	10	41.66	0	0	14	58.33	0	0

I.d. Segment roadside descriptors	11	0	0	0	0	0	11	100	0	0
I.e. Other segment descriptors	0	0	0	0	0	0	0	0	0	0
1.f. Segment traffic flow data	3	2	3	100	0	0	0	0	2	100
I.g. Segment traffic operations/control data	8	1	4	50	1	100	4	50	0	0
I.h. Other supplemental descriptors	0	0	0	0	0	0	0	0	0	0
II. ROADWAY ALIGNMENT DESCRIPTORS (Total number of MIRE Elements = 13)										
I.a. Horizontal curve data	6	0	2	33.33	0	0	4	66.67	0	0
I.b. Vertical grade data	5	0	2	40	0	0	3	60	0	0
III. ROADWAY JUNCTION DESCRIPTORS (Total number of MIRE Elements = 83)										
III.a. At-Grade intersection/junctions	28	4	6	21.43	0	0	22	78.57	4	100
III.b. Interchange and ramp descriptors	23	0	14	60.87	0	0	9	39.13	0	0
Total Number of Elements	117	7	50	42.74	1	0	67	57.26	6	85.71

* R= required, O= optional, N= number, and P=percentage

Since the SCDOT maintains different data inventories collected from state and local highway agencies, the SCDOT was requested to give a feedback on whether the data elements being collected is for state-wide or for samples roadways. elements on the master-sheet were grouped into their categories; roadway segment and alignment-related variables, intersections-related variables, and interchange and ramp-related variables and presented to the data-specialist in SCDOT for response. Based on this survey, it was noticed that most elements that are on the master-sheet listing were available for both state-wide and sample roadways which implies that the state have made effective decisions regarding improving the roadway safety management in terms of the 40% data elements collected. This also indicates that the State still lacks other critical roadway and traffic inventory data necessary for highway safety management, discussed in data quality and gap analysis sections.

Given that safety programs should consider all public roads (MAP-21 requirements), and since most of the collected data reported in the tables above are only collected for portion of the roadway network (e.g., HPMS collected for samples of only National-Aids Roadways), these measured data often give a storing correlation between the multiple safety requirements and the State highway data collection practice. Based on that the scope of the data collection should be extended to include rural minor collectors and locals to support data driven safety decision making.

4.2.1.2 Crash data Inventories

The MMUCC data elements available in the SCDOT databases including the information about location, units, and occupancy for the years of 2007 and 2015 were reviewed in Table 4.7 and Table 4.8, respectively. The following points summarize the analysis results based the assessed crash databases:

1. Both tables show that the crash databases contain only 50% (54 of 110 MMUCC) for the year 2007 and 65% (71 of 110 MMUCC) in the 2015, with 15% relative increase in this period. The data elements were mostly related to crash and vehicle data which both are collected on the scene by the law enforcement officers. However, less crash information related to roadway characteristics were linked from other data sources, where only 3 of 16 data elements for roadway data element obtained after linkage to other data were collected. Liking such data could be an important factor to improve safety analysis.

2. In the Data Elements Collected at the Scene category, information on Crash Data Elements and Vehicle Data Elements exists in most analyzed databases. However, only a very few information on drivers, passengers, and persons involved in the crash databases have been collected.
3. For Crash Data Elements subcategory, the databases of 2007 included 14 of 19 data elements containing information on county, crash location, city, and first harmful event. For year 2015, 2 more data elements were added to the collated data list including the Sources of Information and School Bus information. Both year databases lacked though the case identifiers, and crash classification.
4. In Vehicle Data Elements subcategory, only 15 (18) of 30 data elements in 2007 (2015) provided information on motor vehicle identification number, registration state and year, license plate, use of the motor vehicle, and direction travel before crash. These databases do not include roadway related information such as traffic direction, total number of lanes, and alignment grade of the roadway.
5. In person data elements subcategory, the majority of the databases contain limited data on all persons involved in the crash such as person type, injury status, motorcycle helmet use, driver license jurisdiction, speeding related during the year of 2007 and 2015. Only two data elements regarding the no-motorists involved in the accident were provided in the databases counting for non-motorist location at the crash time, and non-motorist's safety equipment. No data was collected on non-motorist's status prior to crash, number of non-motorists.

6. In the derived and linked data elements subcategory, no information was provided for the year 2007 and only 3 data elements were collected during 2015 such as crash severity, number of motor vehicles involved, and alcohol involvement.
7. Very limited crash data collected at the scene was linked to other driver, traffic, and roadway related conditions, where most information about roadway grade, number of lanes, median width, pavement marking, and intersection information were missing from all reported crashes during 2007 and 2015.

Table 4.7: the number of the SCDOT data elements collected from three data bases in 2007 classified based on different subcategory.

MMUCC Attributes	Total Element in each subcategory	Location	Occupancy	Unites
Data Elements Collected at the Scene				
I Crash Data Elements	19	14	0	1
II Vehicle Data Elements	30	4	1	15
III Person Data Elements				
III.A Level 1: All Persons Involved	5	2	1	0
III.B Level 2: All Occupants	5	0	3	1
III.C Level 3: All Drivers	6	1	0	1
III.D Level 4: All Drivers and Non-motorists	5	0	0	2
III.E Level 5: Non-Motorists (includes occupants of motor vehicles not in transport	7	0	2	0
III.F Level 6: All Injured	1	1	1	0
IV Derived and Linked Data Elements	9	0	0	0
IV Person Data Elements Derived from Collected Data	1	0	1	0
Person Data Elements Obtained After Linkage to Other Data				
Level 3: All Drivers	3	0	0	1
Level 6: All Injured Persons	3	0	2	0
Roadway Data Elements Obtained After Linkage to Other Data				
RL1. Bridge/Structure Identification Number	16	1	0	0

Table 4.8: the number of the SCDOT data elements collected from three data bases in 2015 classified based on different subcategory.

MMUCC Attributes	Total Element in each subcategory	Location	Occupancy	Unites
Data Elements Collected at the Scene				
I Crash Data Elements	19	16	0	2
II Vehicle Data Elements	30	5	2	18
III Person Data Elements				3
III.A Level 1: All Persons Involved	5	0	1	
III.B Level 2: All Occupants	5	0	4	1
III.CLevel 3: All Drivers	6	1	0	4
III.DLevel 4: All Drivers and Non-motorists	5	0	0	1
III.E Level 5: Non-Motorists (includes occupants of motor vehicles not in transport	7	0	2	1
III.F Level 6: All Injured	1	0	1	0
IIII Derived and Linked Data Elements	9	1	0	2
IIIII Person Data Elements Derived from Collected Data	1	0	1	0
Person Data Elements Obtained After Linkage to Other Data				
Level 3. All Drivers	3	0	0	2
Level 6. All Injured Persons	3	0	2	1
Roadway Data Elements Obtained After Linkage to Other Data				
RL1. Bridge/Structure Identification Number	16	2	0	1

4.2.2 Data Quality

The assessment of quality of the SCDOT databases is very important step to improve the current roadway safety data capabilities. This section is divided into two parts; in the first part, the performance measures (Accuracy, Completeness, and Uniformity metrics) were evaluated for the SCDOT roadway, traffic, and crash data elements found MIRE FED, HPMS FE, and the HSM R data requirements; while in the second part, the gaps in the not collected MIRE data listing is evaluated which emphasizes the capability the SCDOT to collect these data times.

4.2.2.1 Performance Measures

In the first part of the data quality analysis, the performance measures evaluated for the critical SCDOT roadway and traffic data elements for roadway safety analysis (i.e., MIRE FDE, HPMS FE, and HSM R) are estimated. The weighting schemes are presented in Figure 4.5 through Figure 4.7 for the MIRE FDE, HPMS FE, and HSM R data elements, respectively. In these figures, the resulting weighting schemes are summarized for each subcategory in MIRE Version 1.0. A full list of all roadway and traffic inventories analysis was exhibited in Appendix (B). Overall, Figure 4.5 and Figure 4.6 indicate that SCDOT reports most of the data elements required by MIRE FED, and HPMS FE, where a large percentage of data elements scored>3.5 maturity level for all performance measures. In comparison, the accuracy and completeness of MIRE FED dataset were relatively higher than HPMS FE datasets, where the MIRE FED dataset covered 6 subcategories and 4 for HPMS FE. In both cases, the segment location linkage had the highest performance in terms of number of data elements and quality of collected data, while the ramps and interchange description scored the lowest performance in case of MIRE FED (<3.00) and HPMS FE (0). This review in general indicates that the coverage of the MIRE FED data sets in SCDOT databases is better than HPMS FE date elements. This is because of the variations in the number of data elements collected in SCDOT databases and the scope of the HPMS databases which contain some elements collected for a limited number of sampled sections (Figure 4.6.b), these results do not cover all public roads. In fact, the elements that are not HPMS data requirements showed lower maturity level such as speed limit<2.

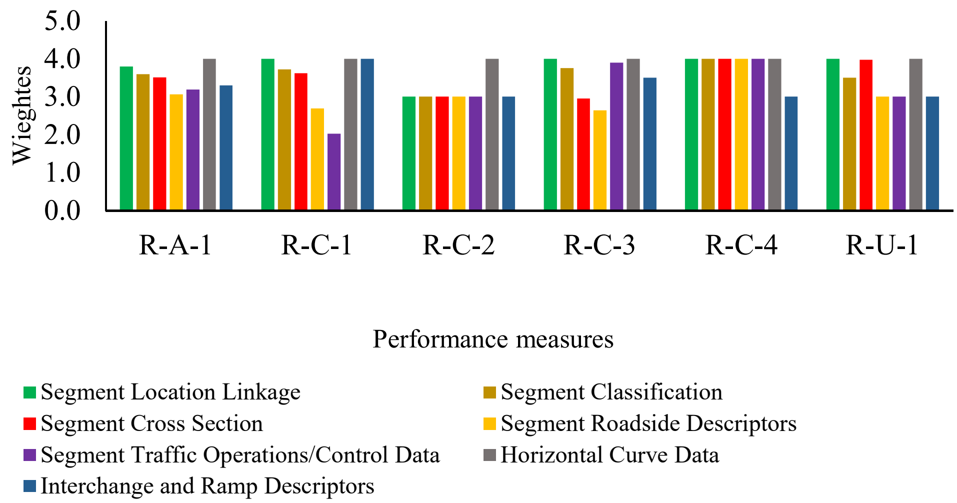

Figure 4.5: Weighted performance measures estimated for the collected SCDOT in MIRE FDE data elements classified on subcategory bases.

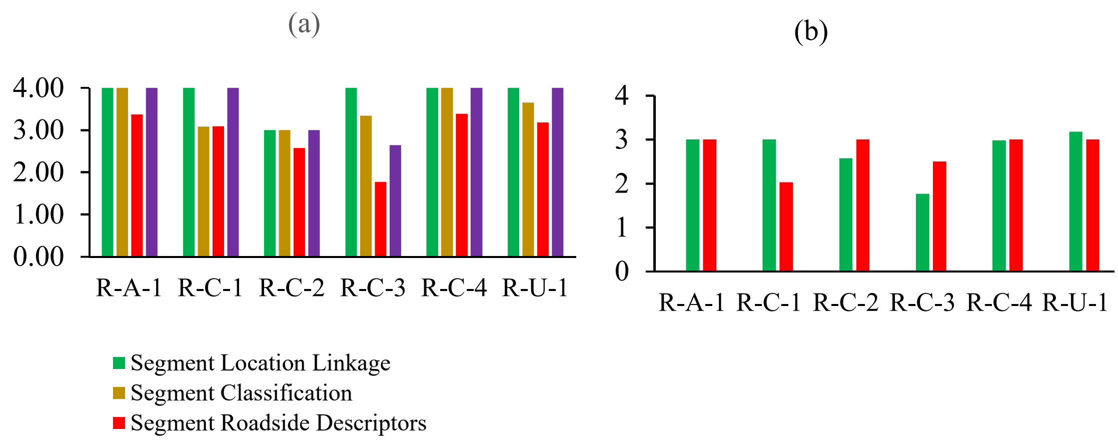

Figure 4.6: Weighted performance measures estimated for the collected SCDOT in HPMS data elements classified on MIRE subcategory bases, (a) HPMS FE, and (b) HPMS Sample.

In Figure 4.7, the MIRE datasets found in SCDOT inventories that satisfy the HSM R data requirements (27 out of 62 total HSM R elements) showed similar performance measures to MIRE FDE and HPMS FE. From these 27 HSM R datasets, the percentage of accuracy, completeness, and uniformity for Segment Roadside Description, Segment Cross Section, and Segment Traffic Operation/ Control Data subcategories were lower than all other MIRE subcategories.

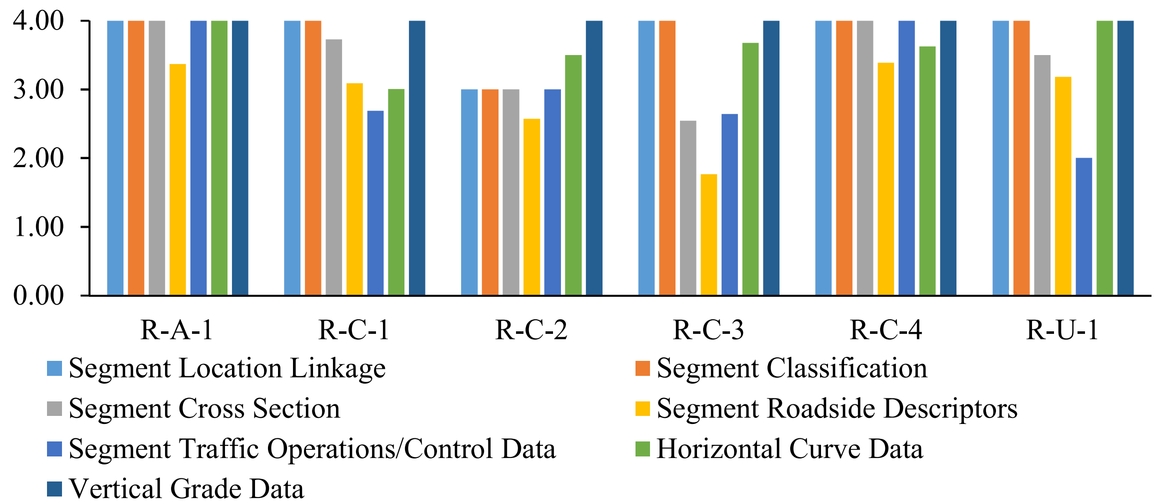

Figure 4.7: Weighted performance measures estimated for the collected SCDOT in HSM required data elements classified on MIRE subcategory bases.

Similar process was followed to conduct performance measures in case of crash data elements compared to MMUCC's crash requirements. Unlike roadways and traffic data, when evaluating crash data, it was found a considerable percentage of cash attributes can accept blanks as a typical entry to indicate not occurring of the events (e.g., Number of Trucks or Buses involved in accidents, Relation to Junction, And Type of Intersection), signed as "Allow Nulls" in the comprehensive summary list shown in Appendices B and C (an example shown in Table 4.9). Therefore, the performance measures for fields with such criteria were overlooked in this process. The result outputs in this step were grouped into three categories including the fields of location of the crash, unites involved in the accident, and the number of occupants related data elements.

Table 4.9: An example of a valid blank entries in case of crash data.

TableName	Field Name	Translation	Description	Min Value	Max Value	Count of Values	Data Type	Allow Nulls	Has Domain
SC_Crash_2015_Loc	ART	Ramp-Type	This area is to be completed only if the collision occurs on a ramp	0	1	146406	Integer	Yes	Yes
	Codes	Frequency	Code Definitions	% Of Competion					
		144453		98.252					
	0	716		0.487					
	1	1854	Entrance	1.261					
SC_Crash_2015_Loc	HZD	Number of Hazardous Vehicles		1	2	84	integer	Yes	Yes
	Codes	Frequency	Code Definitions	% Of Competion					
		146939		99.943					
	1	82		0.056					
	2	2		0.001					
SC_Crash_2015_Loc	BUS	# of Buses		1	2	273	integer	Yes	Yes
	Codes	Frequency	Code Definitions	% Of Competion					
		146750		99.814					
	1	269		0.183					
	2	4		0.003					

The weighted performance measures for the three components of crash data, Location, Unit, Occupants, are presented in Figure 4.8. As seen in this table, the evaluated crash variables showed good data quality as all performance was >3.0. However, the percentage of the evaluate variables is only 55% of the total data elements in the three databases focusing on some variables such as spatial location of crash and linear referencing, system, Route Name and type, Traffic conditions, and traffic conditions. The Location and Units databases have shown higher performance while Occupant shown lower performance because it lacked various information and had varies coding errors ranging from Driver Name and Sex, seat location, Ejection Status. For the other 45%

percentage of the data, we found that there was about 10 unused variables for unknown reasons. For example, investigating agency, Traffic Control Type, Driver License Class and others did not hold any information. The reader can find more information on SCDOT crash data bases on element bases in Appendix (C).

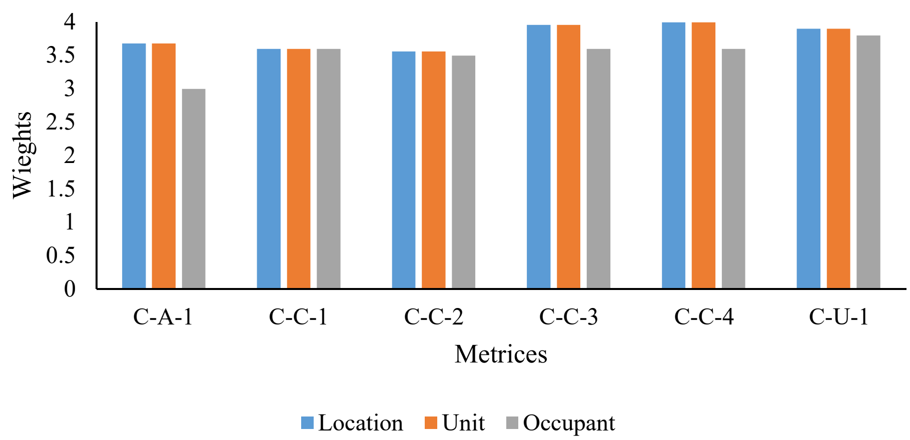

Figure 4.8: An overall performance measures weightings for crash inventories in 2015.

Under Map-21, the SCDOT should establish wide-plan performance measures for all the number and plan program areas. Given most of the data in the inventories are closely related to the HPMS program data coverage (i.e., Federal aid roadways), this means that many of these variables as shown are either not currently collected such as local roads, or collected for samples of SC roadway sections. Finally, the rule of developing performance measure is expected to expand to include all roadways systems and for various assets such as interstate highways, interstate pavement and bridge conditions, etc.

4.2.2.2 Gap Analysis in Databases

For the second part, the gap analysis of MIRE data elements not-contained in SCDOT databases was analyzed. The data from two common safety reporting programs (MIRE FDE, and HPMS) and one analysis tool (HSM) was mapped to the respective SCDOT sate data source. An example of this assessment is shown in Table 4.10. The entire master sheet is provided in Appendix (A).

Table 4.10: An example of mapping SCDOT to MIRE Virion 1.0 with MIRE FDE, HPMS, and HSM R designations.

ID	Attributes	RIMS Attribute Names	MIRE FED	HPMS	Based on Calibration Project			SCDOT		
					HSM RQRD	Facility Type	Data Usage	State	Local	Inventory
	Segment Location Linkage									
1	County Name	COUNTY		Full Extent	R	All	Classification	Y	Y	RIMS, ETEAMS
2	County Code	COUNTY_ID		Full Extent				Y	Y	RIMS
3	Highway District							Y	Y	RIMS
4	Type of Governmental Ownership	GOV_OWNER_ID	Yes	Full Extent				Y	Y	RIMS
5	Specific Governmental Ownership							N	N	
6	City/Local Jurisdiction Name							Y	Y	RIMS,ETEAMS
7	City/Local Jurisdiction Urban Code							N	N	
8	Route Number	RTE_NBR	Yes	Full Extent	R	All	Classification	Y	Y	RIMS
9	Route/Street Name	STREET_NAME	Yes	Full Extent				Y	Y	GIS/ORACLE
10	Begin Point Segment Descriptor	BMP	Yes	Full Extent	R	All	Classification	Y	Y	RIMS
11	End point Segment Descriptor	EMP	Yes	Full Extent	R	All	Classification	Y	Y	RIMS
12	Segment Identifier	RTE_LRS	Yes	Full Extent	R	All	Classification	Y	Y	RIMS
13	Segment Length	Length	Yes	Full Extent	R	All	SPF	Y	Y	RIMS
14	Route Signing	RTE_SGN_ID		Full Extent				Y	Y	RIMS
15	Route Signing Qualifier	RTE_SGN_QL_ID		Full Extent				Y	Y	RIMS
16	Coinciding Route Indicator							Y	Y	RIMS

The review of critical and non-critical safety databases from MIRE and SCDOT data bases revealed that about 60% (122 of 202) of MIRE data elements were not collected (gaps) by the SCDOT including a few numbers of MIRE FDE, HPMS FE, and a considerable number of HSM R. The full list is provided in the Appendix (E), with the designation of data use for safety analysis, an example of few elements is shown in Table 4.11. Data elements with red represent the critical safety basics which would be the first option the State would collects for successful safety assessment for the roadway network; whereas the brown elements indicate the non-critical MIRE data elements for safety assessment. The SCDOT lacks more than 50% of the databases required for HSM safety implementation for the Sates' roadways. These data elements contain information on Segment Cross Section, Segment roadside Description, At Grade Intersection/Junctions, and Approach Descriptors (Each Approach). This table also suggests that the coverage of the MIRE data elements in South Carolina State, as the case with many other States, is highly correlated to HPMS reporting requirements, which covers part of state roadway network. A full comprehensive list of gaps in each MIRE and MMUCC elements are given in Appendices (D, and E), respectively. This data table includes field names, type and range of data entries, and the percentage errors and blank data in each filed. These two tables will be used in the next phase to recognize the suggested new data elements highly recommended to start collecting and expanding span of local domain to include local roads for fulfilling MAP-21 legislations.

Table 4.11: MIRE Version 1.0 data elements identified as gaps in SCDOT roadway and traffic inventories. Red (brown) elements represent critical (non-critical) safety elements based on MIRE FED, HPMS FE, and HSM R requirements.

Segment Location Linkage	**At-Grade Intersection/Junctions**
Specific Governmental Ownership	Unique Junction Identifier (MIRE FDE) (HSM R)
City/Local Jurisdiction Urban Code	Intersection/Junction Number of Legs (HSM R)
Coinciding Route — Minor Route Information	School Zone Indicator
Segment Cross Section	Intersection/Junction Offset Distance
Surface Friction	Intersection/Junction Traffic Control (MIRE FDE) (HSM R)
Surface Friction Date	Signalization Presence/Type
Outside Through Lane Width (HSM R)	Intersection/Junction Lighting (HSM R)
Inside Through Lane Width (HSM R)	Circular Intersection Number of Circulatory Lanes
Cross Slope (HSM R)	Circular Intersection Circulatory Lane Width
Auxiliary Lane Length (HSM R)	Circular Intersection Inscribed Diameter
Reversible Lanes	Circular Intersection Bicycle Facility
Presence/Type of Bicycle Facility	**Approach Descriptors (Each Approach)**
Width of Bicycle Facility	Intersection Identifier for this Approach (HSM R)
Right Paved Shoulder Width (HSM R)	Unique Approach Identifier (MIRE FDE) (HSM R)
Right Shoulder Rumble Strip Presence/Type	Approach AADT (HSM R)
Left Paved Shoulder Width (HSM R)	Approach AADT Year (HSM R)
Left Shoulder Rumble Strip Presence/Type	Approach Mode
Curb Type	Approach Directional Flow (HSM R)
Median Shoulder Rumble Strip Presence/Type	Number of Approach Through Lanes (HSM R)
Median Sideslope	Left Turn Lane Type
Median Sideslope Width	Number of Exclusive Left Turn Lanes (HSM R)
Median Crossover/Left Turn Lane Type	Amount of Left Turn Lane Offset

4.3 *Phase 3* The SCDOT Data Improvement

In this phase, two of current technologies that SCDOT can service to collect datasets that are consistent with those included in the MIRE Version 1.0 data listing have been evaluated. Since there are several factors play an important role in selecting the preferable data collection method (e.g., funding, availability skilled personal, and polices), the research team verified two data collection method including manual data collection from Arial Imaging and Automatic data collection from Ground Based LiDAR to identify which the appropriate technology based on the characteristics and type of data. Table 4.12 shows wither the particular technology has the potential to collect a certain type of data in MIRE Version 1.0. It should be noted that no additional data needed for the data items that are already available for SCDOT. The LiDAR elements are evaluated based on the data collected by Utah DOT, while Arial Imaging elements are based on manual data collection.

Table 4.12 Potential of technologies to collect MIRE elements (NA is either not applicable for data collection using LiDAR technology (2nd column) or Not collected manually (3rd column).

Attributes	Utah Column/Inentory Names/Collection Method	Rating Mannual data collection From Arial Imagry
Segment Cross Section (Cont.)		
Width of Bicycle Facility	Yes/Bike Lanse/Auto	NA
Number of Peak Period Through Lanes	yes/UDOT HPMS Samples2014	NA
Right Shoulder Type	Yes/Shoulders/Auto	2
Right Shoulder Total Width	Yes/Shoulders/Auto	3
Right Paved Shoulder Width	Yes/Shouler/Auto	NA
Right Shoulder Rumble Strip Presence/Type	Yes/Rumblestrips/Auto	2
Left Shoulder Type	Yes/Shoulders/Auto	3
Left Shoulder Total Width	Yes/Shoulders/Auto	NA
Left Paved Shoulder Width	Yes/Shoulders/Auto	NA
Left Shoulder Rumble Strip Presence/Type	Yes/Rumblestrips/Auto	NA
Sidewalk Presence	Yes/Driveways(2014)/Auto	NA
Curb Presence	Yes/Pavem Sect Data-Current	NA
Curb Type	Yes/Pavem Sect Data-Current	NA
Median Type	Yes/Medinas(2014)/Auto	3
Median Width	Yes/Medinas(2014)/Auto	2
Median Barrier Presence/Type	Yes/Barriers(2014)/ Auto	3
Median (Inner) Paved Shoulder Width	Yes/Medinas(2014)/Auto	NA
Median Shoulder Rumble Strip Presence/Type	Yes/Rumblestrips/Auto	NA
Median Sideslope	NA	NA
Median Sideslope Width	NA	NA
Median Crossover/Left Turn Lane Type	NA	NA

Based on the results, very Limited number of attributes can be collected manually from the Arial Imagery such as Segment Cross Section (e.g., Median width, Shoulder type, Surface conditions, Pavement marking category). In addition, the manual collection of the data could create higher uncertainties in collected data this way. Besides, this option can be more challenging (e.g., At-Grade Intersection/Junctions) as shown in the Appendix (F) because of the extensive resources would be required for collecting such data. This table also shows that the ground-based Imagery and LiDAR technologies are capable of collecting the required information for sing elements including location, shape, and the shape of the signs. The reviewed UDOT databases showed that various elements can be collected from technologies using LiDAR technologies based on new updated inventories.

Plan views gathered from imagery or LiDAR technologies along with GPS data can collect as many as 40 MIRE elements, as shown in Appendix (F). The spatial data served to recognize features for elements like the type of interchanges and alignment features, segment cross sections, cross segment characteristics (e.g., length, median width, and height), and the number of different lane types. Similarly, elements such as the surface width, shoulder width, and entry and exit width of circular intersection. However, there are some restrictions in using these technologies; for example, some roadway characteristics in steep terrains cannot be reached using cameras and lasers devices. Also, some other data elements such as intersection skew or entry or exists, curve radius and vertical gradients need more computations and post-possessing work such as tracing and curve fittings.

4.3.1 Develop A Final Proposed SCDOT Dataset

Gap analysis results in the previous phase could be benefit in creating a department-wide strategic minimum data plan to accommodate with the new federally mandated requirements (e.g., MAP-21) necessary for assuring data driven safety assessment across the entire state. Thus, there is a critical need for dedicated resources to undertake a strategic planning process for data collection, maintenance, and management. The developed plan in this step will help the SCDOT for implementations of future requirements based on priority in selecting the data element to be collected. The priority of each roadway, traffic and crash data element was found based on cumulative rank for these data elements, where critical and un-collected data elements were given a rank of 1 (i.e., MIRE FDE, HPMS FE, HSM R, and MMUCC) and 0 for otherwise. Next, the cumulative ranks from the importance of each program/tools were found in in this process. The possible ranks in this process were from 0 for least important to 4 very important in analysis studies. Based on this approach, we found that the highest rank was 2, which means that this element is require by to programs. Finally, we verified whether or not this element can be collected using LiDAR from UDOT data inventories.

The comprehensive product out of this process represent the data elements necessary for the use of the new safety analysis mandated under new improvements such as MAP-21, and is included in the Appendix (G) of this thesis. The list is extensive and promises for new additions to the safety models, softwares, and programs. The results indicated that, although, the SCDOT reports an overall of more than 90% of the MIRE FDE, and HPMS FE and Sample data elements, these reporting requirements lack some important data on Segment Traffic Flow Data and Interchange and Ramp Descriptors, some examples are listed in Table 4.13. In case of HSM, half of required data elements are already being reported by SCDOT. However, the other half of the data elements is not currently collected, provided in the data list as well. Among all critical gap variables, about 71% of the gaps were collected using LiDAR technology at the UDOT. This implies the huge benefits in saving time and efforts of using new LiDAR technology to collected data in South Carolina. Most of the not LiDAR collected gaps were related to horizontal cures, grades, and traffic volumes such as approach AADT.

Table 4.13: Ranking various gaps in the data inventories based on their importance for safety programs/tools and testing ability of LiDAR collection based on UDOT.

Gaps	MIRE R	HPMS FE	HSM R	MMUCC	Rank	Collected By LIDAR at UDOT
Segment Location Linkage					0	
Specific Governmental Ownership	0	0	0	0	0	
City/Local Jurisdiction Urban Code					0	
Coinciding Route — Minor Route Information	0	0	0	0	0	
Segment Cross Section					0	
Surface Friction	0	0	0	0	0	
Surface Friction Date	0	0	0	0	0	
Outside Through Lane Width (HSM R)	0	0	1	0	1	Yes
Inside Through Lane Width (HSM R)	0	0	1	0	1	Yes
Cross Slope (HSM R)	0	0	1	0	1	Yes
Auxiliary Lane Length (HSM R)	0	0	1	0	1	Yes
Reversible Lanes	0	0	0	0	0	
Presence/Type of Bicycle Facility	0	0	0	0	0	
Width of Bicycle Facility	0	0	0	0	0	
Right Paved Shoulder Width (HSM R)	0	0	1	0	1	Yes
Right Shoulder Rumble Strip Presence/Type	0	0	0	0	0	
Left Paved Shoulder Width (HSM R)	0	0	1	0	1	Yes
Left Shoulder Rumble Strip Presence/Type	0	0	0	0	0	
Curb Type	0	0	0	0	0	
Median Shoulder Rumble Strip Presence/Type	0	0	0	0	0	
Median Sideslope	0	0	0	0	0	
Median Sideslope Width	0	0	0	0	0	
Median Crossover/Left Turn Lane Type	0	0	0	0	0	

CHAPTER FIVE

SUMMARY AND RECOMMENDATIONS

5.1 Research Summary Conclusions

This thesis involves analyzing and investigating the state-of the-practice and the state-of-the-art of the current SCDOT roadways, traffic, and crash data inventories to test the readiness of building an effective and efficient data driven safety required by the new legislated MAP-21. The research team identified gaps in the current data and suggested a potential data set with priorities based on safety data reporting needs per two commonly federally mandated reporting programs (MIRE fundamental data and HPMS full extend), and one analysis tool (HSM required data). Six performance measures (e.g., accuracy, completeness, and uniformity) were employed to evaluate the ability of using the current data as a prerequisite to extend the data scope to include state-wide roadway network including local roads. Then, the previous successful implementation of data collection using technologies such as LiDAR and Air Imagery were tested on wither they can provide means to surpass the limitations of collecting safety data.

The review if previous literature (Chapter 2) implies that most States' data including South Carolina (case study) is driven from federally mandated requirement which is in most case a subset of the Model Inventory Management System (MIRE) version 1.0 for roadway and traffic data, or from Minimum Model Uniformity Crash Criteria (MMUCC) for crash data. The literature review finds that most previous reporting was based on the Highway Performance Measures System (HPMS) recommendations, which does not cover local roads, given higher crash rates occur on local roads.

The methodology in Chapter 3 discusses a multi-phased approach which was utilized to organize the safety data requirements and identify the SCDOT data characteristics. This process can be used to enhance the state's safety driven data assessment on the roadway network. A number of specific tasks were undertaken towards achieving the objectives discussed earlier.

The results of this research in Chapter 4 highlights a common relationship between the roadway characteristics, traffic conditions, and the crash rates to conduct a data driven safety assessment on the State's highways. Thus, it is crucial to build a state-wide strategic plan to improve the performance measures (i.e., accuracy, completeness, and uniformity) of the recent data and expand the future data capabilities using new technologies to achieve the new safety goals put up by federal agencies.

Investigating the usage of data driven approach for safety analysis has led to several findings regarding the importance of linking roadway segment characteristics (including local roads) and crash locations (See Figure 5.1), which represents a major key in understanding safety issues on the related roadways features. This highly suggests the need for developing more comprehensive data plans in the SCODT.

Figure 5.1: Crash locations not georeferenced on local roads. Left panel is the previous road shapefile and the right panel is for updated shapefile by our research team.

The previously used technologies such as LiDAR and Arial Imagery found to be promising for new additions to the safety data list, where most roadway characteristics and some traffic controls data were collected successfully in UDOT.

MIRE data elements identified in gap analysis and not collected in SCDOT are prioritized based on their importance for safety analysis and provided in this study for future implementation of data collection plans in South Carolina.

Finally, it is anticipated that the implementation of the research findings would results in long-term economic benefits, less crashes on roadways, and improved traffic flow sand safety.

5.2 Recommendation for Future Work

The enhanced safety data performance measures such as accuracy, completeness, and uniformity would increase understanding of current data and future potentials for collecting more data variables. A follow up research project could investigate additional supplemental data inventories that could impact the data safety performance measures by providing additional data sources if the appropriated linkage is available.

APPENDICES

Appendix A

MASTER SHEET OF ROADWAY ELEMENTS BASED ON MIRE v. 1.0

Color Codes	Description
(green)	HPMS Full Extent, MIRE FE, HSM Required - Collected by SCDOT
(red)	HPMS Full Extent, MIRE FE, HSM Required - Not Collected by SCDOT
(light green)	Not HPMS Full Extent, MIRE FE, HSM Required - Collected by SCDOT
(pink)	Not HPMS Full Extent - Not Collected by SCDOT

ID	Attributes	SCDOT Attribute Name	MIRE	HPMS FE	Based on Calibration Project			SCDOT		
			FDE		HSM RQRD	Facility Type	Data Usage	State	Local	Inventory
	Segment Location Linkage									
1	County Name	COUNTY		Full Extent	R	All	Classification	Y	Y	RIMS,ETEAMS
2	County Code	COUNTY_ID		Full Extent				Y	Y	RIMS
3	Highway District							Y	Y	ITMS
4	Type of Governmental Ownership	GOV_OWNER_ID	Yes	Full Extent				Y	Y	RIMS
5	Specific Governmental Ownership							N	N	
6	City/Local Jurisdiction Name							Y	Y	RIMS,ETEAMS
7	City/Local Jurisdiction Urban Code							N	N	
8	Route Number	RTE_NBR	Yes	Full Extent	R	All	Classification	Y	Y	RIMS
9	Route/Street Name	STREET_NAME	Yes	Full Extent				Y	Y	GIS/ORACLE
10	Begin Point Segment Descriptor	BMP	Yes	Full Extent	R	All	Classification	Y	Y	RIMS
11	End point Segment Descriptor	EMP	Yes	Full Extent	R	All	Classification	Y	Y	RIMS
12	Segment Identifier	RTE_LRS	Yes	Full Extent	R	All	Classification	Y	Y	RIMS
13	Segment Length	Length	Yes	Full Extent	R	All	SPF	Y	Y	RIMS
14	Route Signing	RTE_SGN_ID		Full Extent				Y	Y	RIMS
15	Route Signing Qualifier	RTE_SGN_QL_ID		Full Extent				Y	Y	RIMS
16	Coinciding Route Indicator							Y	Y	RIMS
17	Coinciding Route — Minor Route Information							N	N	
18	Direction of Inventory	RTE_DIR	Yes		R	All	Classification	Y	Y	RIMS
	Segment Classification									
19	Functional Class	RS_FUNC_CLS_ID	Yes	Full Extent and Ramps	R	All	Classification	Y	Y	RIMS
20	Rural/Urban Designation	RURAL_URBAN_ID	Yes	Full Extent and Ramps	R	All	Classification	Y	Y	RIMS
21	Federal Aid/Route Type	RS_FED_OWNER_ID	Yes	Full Extent and Ramps				Y	Y	RIMS

Appendix (A): MASTER SHEET OF ROADWAY ELEMENTS BASED ON MIRE v. 1.0 (Cont.)

ID	Attributes	SCDOT Attribute Name	MIRE	HPMS FE	Based on Calibration Project			SCDOT		
			FDE		HSM RQRD	Facility Type	Data Usage	State	Local	Inventory
22	Access Control	RD_ACCESS_CTRL_ID	Yes	Full Extent and Ramps*, Sample*				Y	Y	RIMS
	Segment Cross Section									
23	Surface Type	SURF_PAV_ID	Yes	Sample	R	All	Classification	Y	Y	RIMS
24	Total Paved Surface Width	RD_SURF_WD_TOTAL			R	All	Crash Assignment	Y	Y	RIMS
25	Surface Friction							N	N	
26	Surface Friction Date							N	N	
27	Pavement Roughness/Condition			Full Extent and Ramps*, Sample*				Y	Y	HPMA
28	Pavement Roughness Date			Full Extent and Ramps*, Sample*				Y	Y	HPMA
29	Pavement Condition (Present Serviceability Rating)			Sample				Y	Y	HPMA
30	Pavement Condition (PSR) Date			Sample				Y	Y	HPMA
31	Number of Through Lanes	THRU_LNS	Yes	Full Extent and Ramps	R	All	Classification	Y	Y	RIMS
32	Outside Through Lane Width				R	All	CMF	N	N	
33	Inside Through Lane Width				R	All	CMF	N	N	
34	Cross Slope				R	CH10	CMF	N	N	
35	Auxiliary Lane Presence/Type	ROUTE_AUX			R	All	Classification	N	N	
36	Auxiliary Lane Length				R	All	Crash Assignment	N	N	
37	HOV Lane Presence/Types	RS_HOV_TYPE_ID		Full Extent	R	All	Classification	N	N	
38	HOV Lanes	RS_NBR_HOV_LANES		Full Extent	R	All	Classification	N	N	
39	Reversible Lanes				R	All	Classification	N	N	
40	Presence/Type of Bicycle Facility							N	N	
41	Width of Bicycle Facility							N	N	
42	Number of Peak Period Through Lanes			Sample				Y	Y	RIMS
43	Right Shoulder Type			Sample	R	CH10,18	CMF	Y	Y	RIMS
44	Right Shoulder Total Width			Sample	R	CH10,18	CMF	Y	Y	RIMS
45	Right Paved Shoulder Width				R	CH10,18	CMF	N	N	
46	Right Shoulder Rumble Strip Presence/Type				R	CH10,18	CMF	N	N	

Appendix (A): MASTER SHEET OF ROADWAY ELEMENTS BASED ON MIRE v. 1.0 (Cont.)

ID	Attributes	SCDOT Attribute Name	MIRE	HPMS FE	Based on Calibration Project			SCDOT		
			FED		HSM RQRD	Facility Type	Data Usage	State	Local	Inventory
47	Left Shoulder Type				R	CH10,18	CMF	Y	Y	RIMS
48	Left Shoulder Total Width			Sample	R	CH10,18	CMF	Y	Y	RIMS
49	Left Paved Shoulder Width				R	CH10,18	CMF	N	N	
50	Left Shoulder Rumble Strip Presence/Type				R	CH10,18	CMF	N	N	
51	Sidewalk Presence							Y	Y	RIMS
52	Curb Presence							Y	Y	RIMS
53	Curb Type							N	N	
54	Median Type	RD_MED_ID	Yes	Sample	R	All	Classification	Y	Y	RIMS
55	Median Width	RD_MED_WD		Sample	R	All	CMF	Y	Y	RIMS
56	Median Barrier Presence/Type			Sample	R	CH10,11,18	CMF	Y	Y	RIMS
57	Median (Inner) Paved Shoulder Width							Y	Y	RIMS
58	Median Shoulder Rumble Strip Presence/Type				R	CH10,18	CMF	N	N	
59	Median Sideslope							N	N	
60	Median Sideslope Width							N	N	
61	Median Crossover/Left Turn Lane Type				R	All	Classification	N	N	
	Segment Roadside Descriptors									
62	Roadside Clearzone Width				R	CH10,18	CMF	N	N	
63	Right Sideslope				R	CH11	CMF	N	N	
64	Right Sideslope Width							N	N	
65	Left Sideslope				R	CH11	CMF	N	N	
66	Left Sideslope Width							N	N	
67	Roadside Rating				R	CH10	CMF	N	N	
68	Major Commercial Driveway Count				R	CH12	SPF	N	N	
69	Minor Commercial Driveway Count				R	CH12	SPF	N	N	
70	Major Residential Driveway Count				R	CH12	SPF	N	N	
71	Minor Residential Driveway Count				R	CH12	SPF	N	N	
72	Major Industrial/Institutional Driveway Count				R	CH12	SPF	N	N	
73	Minor Industrial/Institutional Driveway Count				R	CH12	SPF	N	N	
74	Other Driveway Count				R	CH12	SPF	N	N	

Appendix (A): MASTER SHEET OF ROADWAY ELEMENTS BASED ON MIRE v. 1.0 (Cont.)

ID	Attributes	SCDOT Attribute Name	MIRE	HPMS FE	Based on Calibration Project			SCDOT		
			FDE		HSM RQRD	Facility Type	Data Usage	State	Local	Inventory
75	Terrain Type			Sample				Y	Y	RIMS
76	Number of Signalized Intersections in Segment			Sample				Y	Y	RIMS
77	Number of Stop-Controlled Intersections in Segment			Sample				Y	Y	RIMS
78	Number of Uncontrolled/Other Intersections in Segment			Sample				Y	Y	RIMS
	Segment Traffic Flow Data									
79	Annual Average Daily Traffic (AADT)	TR_FAADT	Yes	Full Extent and Ramps	R	All	SPF	Y	Y	TDMA/ AADT
80	AADT Year	TR_FAADT_YEAR	Yes	Full Extent and Ramps	R	All	SPF	Y	Y	TDMA/ AADT
81	AADT Annual Escalation Percentage							N	N	
82	Percent Single Unit Trucks or Single Truck AADT	RS_TRUCK_RTE_ID		Full Extent and Ramps*, Sample*				Y	Y	TDMA
83	Percent Combination Trucks or Combination Truck AADT	RS_TRUCK_RTE_SEG_SEQ		Full Extent and Ramps*, Sample*				Y	Y	TDMA
84	Percentage Trucks or Truck AADT							Y	Y	TDMA
85	Total Daily Two-Way Pedestrian Count/Exposure				O	CH12	SPF	N	N	
86	Bicycle Count/Exposure				O	CH12	SPF	N	N	
87	Motorcycle Count or Percentage			Full Extent				Y	Y	
88	Hourly Traffic Volumes (or Peak and Offpeak AADT)				R	CH18	CMF	Y	Y	TPAS
89	K-Factor			Sample				Y	Y	TDMA
90	Directional Factor			Sample				Y	Y	TDMA

Appendix (A): MASTER SHEET OF ROADWAY ELEMENTS BASED ON MIRE v. 1.0 (Cont.)

ID	Attributes	SCDOT Attribute Name	MIRE	HPMS FE	Based on Calibration Project			SCDOT		
			FDE		HSM RQRD	Facility Type	Data Usage	State	Local	Inventory
	Vertical Grade Data									
115	Grade Identifiers and Linkage Elements				R	CH10	CMF	N	N	
116	Vertical Alignment Feature Type				R	CH10	CMF	N	N	
117	Percent of Gradient			Sample*	R	CH10	CMF	Y	Y	RIMS
118	Grade Length				R	CH10	CMF	Y	Y	RIMS
119	Vertical Curve Length				R	CH10	CMF	N	N	
	At-Grade Intersection/Junctions									
120	Unique Junction Identifier		Yes		R	All	Classification	N	N	
121	Type of Intersection/Junction	SGNLZTN_ID			R	All	Classification	Y	Y	RIMS
122	Location Identifier for Road 1 Crossing Point		Yes		R	All	Classification	Y	Y	RIMS
123	Location Identifier for Road 2 Crossing Point		Yes		R	All	Classification	Y	Y	RIMS
124	Location Identifier for Additional Road Crossing Points				R	All	Classification	Y	Y	RIMS
125	Intersection/Junction Number of Legs				R	All	Classification	N	N	
126	Intersection/Junction Geometry	JCT	Yes		R	All	Classification	Y	Y	RIMS
127	School Zone Indicator				O	CH12	CMF	N	N	
128	Railroad Crossing Number							Y	Y	RIMS
129	Intersecting Angle				R	CH10,11	CMF	Y	Y	RIMS
130	Intersection/Junction Offset Distance				R	All	Classification	N	N	
131	Intersection/Junction Traffic Control		Yes		R	All	Classification	N	N	
132	Signalization Presence/Type				R	All	Classification	N	N	
133	Intersection/Junction Lighting				R	All	CMF	N	N	
134	Circular Intersection Number of Circulatory Lanes							N	N	
135	Circular Intersection Circulatory Lane Width							N	N	
136	Circular Intersection Inscribed Diameter							N	N	
137	Circular Intersection Bicycle Facility							N	N	

Appendix (A): MASTER SHEET OF ROADWAY ELEMENTS BASED ON MIRE v. 1.0 (Cont.)

ID	Attributes	SCDOT Attribute Name	MIRE	HPMS FE	Based on Calibration Project			SCDOT		
			FED		HSM RQRD	Facility Type	Data Usage	State	Local	Inventory
	Approach Descriptors (Each Approach)									
138	Intersection Identifier for this Approach				R	All	Classification	N	N	
139	Unique Approach Identifier		Yes		R	All	Classification	N	N	
140	Approach AADT				R	All	SPF	N	N	
141	Approach AADT Year				R	All	SPF	N	N	
142	Approach Mode				R	All	Classification	N	N	
143	Approach Directional Flow				R	All	Classification	N	N	
144	Number of Approach Through Lanes				R	All	Classification	N	N	
145	Left Turn Lane Type							N	N	
146	Number of Exclusive Left Turn Lanes				R	CH10,CH11,CH12	CMF	N	N	
147	Amount of Left Turn Lane Offset							N	N	
148	Right Turn Channelization				R	CH12	CMF	N	N	
149	Traffic Control of Exclusive Right Turn Lanes							N	N	
150	Number of Exclusive Right Turn Lanes				R	CH10,CH11,CH12	CMF	N	N	
151	Length of Exclusive Left Turn Lanes				O	All	Crash Assignment	N	N	
152	Length of Exclusive Right Turn Lanes				O	All	Crash Assignment	N	N	
153	Median Type at Intersection				O	CH12	CMF	N	N	
154	Approach Traffic Control				R	All	Classification	N	N	
155	Approach Left Turn Protection				R	CH12	CMF	N	N	
156	Signal Progression							N	N	
157	Crosswalk Presence/Type				R	CH12	CMF	N	N	
158	Pedestrian Signalization Type							N	N	
159	Pedestrian Signal Special Features							N	N	
160	Crossing Pedestrian Count/Exposure				R	CH12	SPF	N	N	
161	Left/Right Turn Prohibitions				R	CH12	CMF	N	N	
162	Right Turn-On-Red Prohibitions				R	CH12	CMF	N	N	

Appendix (A): MASTER SHEET OF ROADWAY ELEMENTS BASED ON MIRE v. 1.0 (Cont.)

ID	Attributes	SCDOT Attribute Name	MIRE	HPMS FE	Based on Calibration Project			SCDOT		
			FED		HSM RQRD	Facility Type	Data Usage	State	Local	Inventory
163	Left Turn Counts/Percent							N	N	
164	Year of Left Turn Counts/Percent							N	N	
165	Right Turn Counts/Percent							N	N	
166	Year of Right Turn Counts/Percent							N	N	
167	Transverse Rumble Strip Presence							N	N	
168	Circular Intersection Entry Width							N	N	
169	Circular Intersection Number of Entry Lanes							N	N	
170	Circular Intersection Presence/Type of Exclusive Right Turn Lane							N	N	
171	Circular Intersection Entry Radius							N	N	
172	Circular Intersection Exit Width							N	N	
173	Circular Intersection Number of Exit Lanes							N	N	
174	Circular Intersection Exit Radius							N	N	
175	Circular Intersection Pedestrian Facility							N	N	
176	Circular Intersection Crosswalk Location							N	N	
177	Circular Intersection Island Width							N	N	
	Interchange and Ramp Descriptors									
178	Unique Interchange Identifier	RA_ROUTNUM	Yes		R	CH19	Classification	Y	Y	RIMS
179	Location Identifier for Road 1 Crossing Point	RIMS_LRS			R	CH19	Classification	Y	Y	RIMS
180	Location Identifier for Road 2 Crossing Point				R	CH19	Classification	Y	Y	RIMS
181	Location Identifier for Additional Road Crossing Points				R	CH19	Classification	Y	Y	RIMS

Appendix (A): MASTER SHEET OF ROADWAY ELEMENTS BASED ON MIRE v. 1.0 (Cont.)

ID	Attributes	SCDOT Attribute Name	MIRE	HPMS FE	Based on Calibration Project			SCDOT		
			FED		HSM RQRD	Facility Type	Data Usage	State	Local	Inventory
182	Interchange Type		Yes		R	CH19	Classification	N	N	
183	Interchange Lighting							N	N	
184	Interchange Entering Volume				R	CH19	SPF	N	N	
185	Interchange Identifier for this Ramp				R	CH19	Classification	N	N	
186	Unique Ramp Identifier	RA_RAMPID			R	CH19	Classification	Y	Y	RIMS
187	Ramp Length	RA_LENG	Yes		R	CH19	SPF	Y	Y	RIMS
188	Ramp Acceleration Lane Length				R	CH19	CMF	N	N	
189	Ramp Deceleration Lane Length				R	CH19	CMF	N	N	
190	Ramp Number of Lanes	RA_LANES			R	CH19	Classification	Y	Y	RIMS
191	Ramp AADT	RIMS_ADT	Yes		R	CH19	SPF	Y	Y	TDMA
192	Year of Ramp AADT	RIMS_ADT_RAMP	Yes		R	CH19	SPF	Y	Y	TDMA
193	Ramp Metering				R	CH19	Classification	N	N	
194	Ramp Advisory Speed Limit							N	N	
195	Roadway Type at Beginning Ramp Terminal	RA_ROUTTYP	Yes		R	CH19	Classification	Y	Y	RIMS
196	Roadway Feature at Beginning Ramp Terminal				R	CH19	Classification	N	N	
197	Location Identifier for Roadway at Beginning Ramp Terminal	RA_BEGMILE	Yes		R	CH19	Classification	Y	Y	RIMS
198	Location of Beginning Ramp Terminal Relative to Mainline Flow				R	CH19	Classification	N	N	
199	Roadway Type at Ending Ramp Terminal	RA_RAMPID	Yes		R	CH19	Classification	Y	Y	RIMS
200	Roadway Feature at Ending Ramp Terminal				R	CH19	Classification	N	N	
201	Location Identifier for Roadway at Ending Ramp Terminal	RA_ENDMILE	Yes		R	CH19	Classification	Y	Y	RIMS
202	Location of Ending Ramp Terminal Relative to Mainline Flow				R	CH19	Classification	N	N	RIMS

Appendix B

A COMPREHENSIVE SUMMARY LIST OF ROADWAY AND TRAFFIC DATA INVENTORIES ASSESSMENT

Attribute Name	Attribute Description	Min Value	Max Value	Cout of Values	DataType	Allow Nulls	Has Domain
COUNTY	County Name	1	46	173888	Ineger	No	Yes
RTE_NBR	Route Number	1	10759	173888	Ineger	No	Yes
BMP	Begin Point Segment Descriptor	0	220.86	173888	Real	No	Yes
EMP	End point Segment Descriptor	0.001	999.06	173888	Real	No	Yes
RTE_LRS	Segment Identifier	01020017800E	46120000201U	173888	Mixed	No	Yes
RTE_SGN_QL_ID	Route Signing Qualifier	1	1	2	Number	Yes	Yes
RTE_SGN_ID	Route Signing	1	5	311	Number	Yes	Yes
RTE_DIR	Direction of Inventory	E	W	173888	Text	No	Yes
RS_FUNC_CLS_ID	Functional Class	1	18	171226	Number	Yes	Yes
IS_URBAN	Rural/Urban Designation	0	1	9622	Number	No	Yes
RS_FED_OWNER_ID	Federal Aid/Route Type	1	8	187	Number	Yes	Yes
RD_ACCESS_CTRL_ID	Access Control	0	2	171226	Number	No	Yes
RD_SURF_WD_TOTAL	Total Paved Surface Width	0	168	171226	Number	Yes	No

Appendix (B): A comprehensive summary list of roadway and traffic data inventories assessment (Cont.)

Attribute Name	Attribute Description	Min Value	Max Value	Cout of Values	DataType	Allow Nulls	Has Domain
RTE_AUX_ID	Auxiliary Lane Presence/Type	0	98	173888	Number	No	Yes
RS_HOV_TYPE_ID	HOV Lane Presence/Typese			0			
RS_NBR_HOV_LANES	RS_NBR_HOV_LANES			0			
RD_MED_ID	Median Type	0	8	171226	Number	Yes	Yes
RD_MED_WD	Median Width	0	400	171226	Number	Yes	No
TR_FAADT	Annual Average Daily Traffic (AADT)	0	165900	173140	Number	Yes	No
TR_FAADT_YEAR	AADT Year	2001	2016	173283	Number	Yes	Yes
RS_TRUCK_RTE_SEG_SEQ	Percent Combination Trucks or Combination Truck AADT	1	99	4097	Number	Yes	Yes
RTE_DIR	One/Two-Way Operations	E	W	173888	Number	No	Yes
RS_TOLL_TYPE_ID	Toll Facility	1	1	35	Number	Yes	Yes
SURF_PAV_ID	Surface Type	1	7	9627	Number	Yes	Yes
THRU_LNS	Number of Through Lanes	0	9	123309	Number	Yes	Yes
SPEED_LIMIT	Speed Limit	0	1	#REF!	Number	Yes	Yes
PCT_STRIPED_PASS	Passing Zone Percentage	0	4	#REF!	Number	Yes	Yes
SGNLZTN_ID	Type of Intersection/Junction	"1	987	3453	Number	No	Yes
JCT	Intersection/Junction Geometry	1	99	64991	Integer	Yes	Yes
RA_ROUTNUM	Unique Interchange Identifier	1	8135	61376	Integer	No	Yes
RIMS_LRS	Location Identifier for Road 1 Crossing Point	01020017800E	46090152000E	60424	Integer	No	Yes

Appendix (B): A comprehensive summary list of roadway and traffic data inventories assessment (Cont.)

Attribute Name	Attribute Description	Min Value	Max Value	Cout of Values	DataType	Allow Nulls	Has Domain
RA_RAMPID	Unique Ramp Identifier		I-	61376	Integer	No	Yes
RA_LANES	Ramp Number of Lanes	0	8	62348	Ineger	NO	Yes
RA_ROUTTYP	Roadway Type at Beginning Ramp Terminal	I-	US	62348	Ineger	NO	Yes
RA_BEGMILE	Location Identifier for Roadway at Beginning Ramp Terminal	0	300	62348	Ineger	No	Yes
RA_RAMPID	Roadway Type at Ending Ramp Terminal		I-	62348	Ineger	Yes	Yes
RA_ENDMILE	Location Identifier for Roadway at Ending Ramp Terminal	0.01	300.06	62348	Ineger	Yes	Yes
RIMS_ADT	Ramp AADT	25	149800	12495	Integer	Yes	Yes
RIMS_YEAR	Ramp AADT	2010	2010	12495	Integer	Yes	Yes
GOV_OWNER_ID	Type of Government Ownership	1	4	9961	Integer	No	Yes
Rt_Sh_Trt	Right Shoulder Type	-1	3	75195	Integer	Yes	Yes
Rt_Sh_Widt	Right Inside Shoulder Width (ft)	0	23	75195	integer	No	yes
L_Sh_Trt	Left Shoulder Treatment	-1	3	75195	integer	No	yes
Sh_Widt_li	Left Inside Shoulder Width (ft)	0	17	75195	integer	No	yes
Route_Divi	Route Divided	0	1	75195	integer	No	yes
HorCur	Horizontal Curvature (1/Ave Radius (ft))	6.5031E-11	203.0638429	75195	varies	No	No

Appendix C

A COMPREHENSIVE SUMMARY LIST OF CRASH DATA INVENTORIES ASSESSMENT

TableName	Attribute Name	Attribute Description	Min Value	Max Value	Cout of Values	Data Type	Allow Nulls	Has Domain	Percent Filled	Percent Blanks
SC_Crash_2015_Loc	DLR	Lane/Ramp Direction	E	W	144001	Text	No	Yes	97.94	2.06
SC_Crash_2015_Loc	BDI	Base Distance Offset Indicator	F	M	146425	Text	No	Yes	99.5	0.5
SC_Crash_2015_Loc	RPI	Milepost/Grip Reference Indicator			0	NA	Yes	No	0	100
SC_Crash_2015_Loc	WCC	Weather Condition	1	9	146956	Integer	No	Yes	99.95	0.05
SC_Crash_2015_Loc	LOC	Locale			0	NA	No	NO	100	0
SC_Crash_2015_Loc	RSC	Road Surface	1	9	147018	Integer	No	Yes	100	0
SC_Crash_2015_Loc	TSF	Traffic Control Function			0	NA	No	No	0	100
SC_Crash_2015_Loc	FHE	FIRST HARMFUL EVENT	1	69	147021	Integer	No	Yes	100	0
SC_Crash_2015_Loc	ANO	Accident Number	1504326	16024065	147022	Integer	No	Yes	99.9	0.1
SC_Crash_2015_Loc	ALS	Collision Street Name	0	ZOAR RD	128687	text	No	No	85.75	14.25
SC_Crash_2015_Loc	BDO	Base Distance Offset	0	4724	146217	Integer	No	No	99.45	0.55
SC_Crash_2015_Loc	MPT	Mile Post or Grid			0	NA	No	No	0	100
SC_Crash_2015_Loc	FSU	Special Use Area			0	NA	No	Yes	0	100
SC_Crash_2015_Loc	BRA	Base Route Auxiliary	0	9	145834	integer	No	yes	99	1

Appendix (C): A comprehensive summary list of crash data inventories assessment (Cont.)

Table Name	Attribute Name	Attribute Description	Min Value	Max Value	Cout of Values	Data Type	Allow Nulls	Has Domain	Percent Filled	Percent Blanks
SC_Crash_2015_Loc	SIC	Second Route Category	1	6	147019	integer	No	yes	99.5	0.5
SC_Crash_2015_Loc	MAC	Manner of Collision	0	99	146888	integer	No	Yes	99.9	0.1
SC_Crash_2015_Loc	WZN	Work Zone	1	2	146985	integer	Yes	yes	99	1
SC_Crash_2015_Unit	AUN	Unit Number	1	9	275632	integer	No	yes	99.6	0.4
SC_Crash_2015_Unit	DRAC	Dr-Ped-Race	A	W	269536	text	No	yes	97	3
SC_Crash_2015_Unit	DLS	Dr-Lic-State	AB	ZA	253552	text	No	yes	99	1
SC_Crash_2015_Unit	DLC	Driver Licens Class	-	Z	248742	text	No	NO	0	100
SC_Crash_2015_Unit	NAM	Dr-Ped-Name	,CCREA	ZYLICZ	275632	text	No	NO	99.63	0.37
SC_Crash_2015_Unit	UTC	Unit-Type	1	99	275662	integer	No	Yes	99.64	0.36
SC_Crash_2015_Unit	VUC	Vehicle-Use	1	41	275539	integer	No	Yes	99.60	0.40
SC_Crash_2015_Unit	API	Action Prior to Impact	1	99	275629	integer	No	yes	99.63	0.37
SC_Crash_2015_Unit	VEW	Vehic-Weight-Code	1	99	3497	yes	No	yes	1.26	98.74
SC_Crash_2015_Unit	VIN	VEHICLE IDENTIFICATION NUMBER	!FAFP34N47W 358678	ZT1BR32E2 5C448780	217165	Text/Intege r	No	No	72.607	27.392996
SC_Crash_2015_Unit	MHE	Most-Harmful-Event	1	69	274986		No	yes	99.39744	0.6025599
SC_Crash_2015_Unit	MAN	Manner-of-Collision	0	99	147023	integer	No	yes	53.14347	46.856531
SC_Crash_2015_Unit	MDA	Most-Deformed-Area	0	99	275310	integer	No	yes	99.51455	0.4854457
SC_Crash_2015_Occ	OSEX	Sex	F	U	364629	text	No	yes	96.61683	3.3831747
SC_Crash_2015_Occ	EJE	Ejection Status	1	9	372995	integer	Yes	yes	98.83359	1.166411

Appendix D

GAP ANALYSIS IN ROADWAY AND TRAFFIC DATA AT SCDOT
Red elements are critical for safety analysis, brown elements are not critical (both Not collected)

Segment Location Linkage	At-Grade Intersection/Junctions
Specific Governmental Ownership	Unique Junction Identifier (MIRE FDE) (HSM R)
City/Local Jurisdiction Urban Code	Intersection/Junction Number of Legs (HSM R)
Coinciding Route — Minor Route Information	School Zone Indicator
Segment Cross Section	Intersection/Junction Offset Distance
Surface Friction	Intersection/Junction Traffic Control (MIRE FDE) (HSM R)
Surface Friction Date	Signalization Presence/Type
Outside Through Lane Width (HSM R)	Intersection/Junction Lighting (HSM R)
Inside Through Lane Width (HSM R)	Circular Intersection Number of Circulatory Lanes
Cross Slope (HSM R)	Circular Intersection Circulatory Lane Width
Auxiliary Lane Length (HSM R)	Circular Intersection Inscribed Diameter
Reversible Lanes	Circular Intersection Bicycle Facility
Presence/Type of Bicycle Facility	**Approach Descriptors (Each Approach)**
Width of Bicycle Facility	Intersection Identifier for this Approach (HSM R)
Right Paved Shoulder Width (HSM R)	Unique Approach Identifier (MIRE FDE) (HSM R)
Right Shoulder Rumble Strip Presence/Type	Approach AADT (HSM R)
Left Paved Shoulder Width (HSM R)	Approach AADT Year (HSM R)
Left Shoulder Rumble Strip Presence/Type	Approach Mode
Curb Type	Approach Directional Flow (HSM R)
Median Shoulder Rumble Strip Presence/Type	Number of Approach Through Lanes (HSM R)
Median Sideslope	Left Turn Lane Type
Median Sideslope Width	Number of Exclusive Left Turn Lanes (HSM R)
Median Crossover/Left Turn Lane Type	Amount of Left Turn Lane Offset

Appendix (D): GAP ANALYSIS IN ROADWAY AND TRAFFIC DATA AT SCDOT
Red elements are critical for safety analysis, brown elements are not critical (both Not collected)

Segment Roadside Descriptors	**Approach Descriptors (Each Approach) (Cont..)**
Roadside Clearzone Width	Right Turn Channelization (HSM R)
Right Sideslope (HSM R)	Traffic Control of Exclusive Right Turn Lanes
Right Sideslope Width	Number of Exclusive Right Turn Lanes (HSM R)
Left Sideslope (HSM R)	Length of Exclusive Left Turn Lanes
Left Sideslope Width	Length of Exclusive Right Turn Lanes
Roadside Rating (HSM R)	Median Type at Intersection
Major Commercial Driveway Count (HSM R)	Approach Traffic Control
Minor Commercial Driveway Count (HSM R)	Approach Left Turn Protection (HSM R)
Major Residential Driveway Count (HSM R)	Signal Progression
Minor Residential Driveway Count (HSM R)	Crosswalk Presence/Type
Major Industrial/Institutional Driveway Count (HSM R)	Pedestrian Signalization Type
Minor Industrial/Institutional Driveway Count (HSM R)	Pedestrian Signal Special Features
Other Driveway Count (HSM R)	Crossing Pedestrian Count/Exposure
Segment Traffic Flow Data	Left/Right Turn Prohibitions
AADT Annual Escalation Percentage	Right Turn-On-Red Prohibitions (HSM R)
Total Daily Two-Way Pedestrian Count/Exposure	Left Turn Counts/Percent
Bicycle Count/Exposure	Year of Left Turn Counts/Percent
Motorcycle Count or Percentage (HPMS FE)	Right Turn Counts/Percent
Segment Traffic Operations/Control Data	Year of Right Turn Counts/Percent
Truck Speed Limit	Transverse Rumble Strip Presence
Nighttime Speed Limit	Circular Intersection Entry Width
85th Percentile Speed	Circular Intersection Number of Entry Lanes

Appendix (D): GAP ANALYSIS IN ROADWAY AND TRAFFIC DATA AT SCDOT
Red elements are critical for safety analysis, brown elements are not critical (both Not collected)

Segment Traffic Operations/Control Data (Cont..)	Approach Descriptors (Each Approach) (Cont..)
Mean Speed	Circular Intersection Presence/Type of Exclusive Right Turn Lane
School Zone Indicator	Circular Intersection Entry Radius
On-Street Parking Presence (HSM R)	Circular Intersection Exit Width
Roadway Lighting (HSM R)	Circular Intersection Number of Exit Lanes
Edgeline Presence/Width	Circular Intersection Exit Radius
Centerline Presence/Width	Circular Intersection Pedestrian Facility
Centerline Rumble Strip Presence/Type (HSM R)	Circular Intersection Crosswalk Location
Horizontal Curve Data	Circular Intersection Island Width
Curve Identifiers and Linkage Elements (HSM R)	**Interchange and Ramp Descriptors**
Curve Feature Type (HSM R)	Interchange Type (MIRE FDE)
Curve Superelevation (HSM R)	Interchange Lighting
Horizontal Transition/Spiral Curve Presence (HSM R)	Interchange Entering Volume
Horizontal Curve Intersection/Deflection Angle	Interchange Identifier for this Ramp
Horizontal Curve Direction	Ramp Acceleration Lane Length
Vertical Grade Data	Ramp Deceleration Lane Length
Grade Identifiers and Linkage Elements (HSM R)	Ramp Metering
Vertical Alignment Feature Type (HSM R)	Ramp Advisory Speed Limit
Vertical Curve Length	Roadway Feature at Beginning Ramp Terminal
	Location of Beginning Ramp Terminal Relative to Mainline Flow
	Roadway Feature at Ending Ramp Terminal

Appendix E

GAP ANALYSIS IN CRASH DATA AT SCDOT

MMUCC Attributes	
Case Identifier	P27. Unit Number of Motor Vehicle Striking Non-Motorist
Crash Classification	IIII Derived and Linked Data Elements
II Vehicle Data Elements	CD3. Number of Motorists
V6. Motor Vehicle Model Year	CD4. Number of Non-Motorists
V7. Motor Vehicle Model	CD5. Number of Non-Fatally Injured Persons
V15. Total Lanes in Roadway	CD7. Alcohol Involvement
V16. Roadway Alignment and Grade	CD8. Drug Involvement
V22. Bus Use	CD9. Day of Week
V23. Hit and Run	IV Person Data Elements Derived From Collected Data
V28. Vehicle Configuration**	Person Data Elements Obtained After Linkage to Other Data
V29. Cargo Body Type**	Level 3: All Drivers
V30. Hazardous Materials (Cargo Only)**	PL3. Drug Test Result
III Person Data Elements	Level 6: All Injured Persons
III-A Level 1: All Persons Involved	PL5. Injury Diagnosis

MMUCC Attributes	
P4. Person Type	Roadway Data Elements Obtained After Linkage to Other Data
P5. Injury Status	RL1. Bridge/Structure Identification Number
III-B Level 2: All Occupants	RL2. Roadway Curvature
P8. Restraint Systems / Motorcycle Helmet Use	RL3. Grade
III-CLevel 3: All Drivers	RL4. Part of National Highway System
P11. Driver License Jurisdiction	RL5. Roadway Functional Class
P16. Driver Distracted By	RL7. Widths of Lane(s) and Shoulder(s)
III-D Level 4: All Drivers and Non-motorists	RL8. Width of Median
P17. Condition at Time of the Crash	RL9. Access Control
P18. Law Enforcement Suspects Alcohol Use	RL10. Railway Crossing ID
P20. Law Enforcement Suspects Drug Use	RL11. Roadway Lighting
P21. Drug Test	RL12. Pavement Markings, Longitudinal
III -E Level 5: Non-Motorists (includes occupants of motor vehicles not in transport	RL13. Presence/Type of Bicycle Facility
and occupants of non-motor vehicle transportation devices)	RL15. Mainline Number of Lanes at Intersection
P22. Non-Motorist Number	RL17. Total Volume of Entering Vehicles
P23. Non-Motorist Action/Circumstance Prior to Crash	

Appendix F

POTENTIAL OF TECHNOLOGIES TO COLLECT MIRE ELEMENTS

Attributes	Utah Column/Inentory Names/Collection Method	Rating Mannual data collection From Arial Imagry
Segment Location Linkage		
County Name	NA*	NA*
County Code	NA	NA
Highway District	NA	NA
Type of Governmental Ownership	NA	NA
Specific Governmental Ownership	NA	NA
City/Local Jurisdiction Name	NA	NA
City/Local Jurisdiction Urban Code	NA	NA
Route Number	Yes/HPMS sample	NA
Route/Street Name	NA	NA
Begin Point Segment Descriptor	Yes/HPMS sample	NA
End point Segment Descriptor	Yes/HPMS sample	NA
Segment Identifier	Yes/HPMS sample	NA
Segment Length	Yes/HPMS sample	NA
Route Signing	Yes/HPMS sample	NA
Route Signing Qualifier	Yes/HPMS sample	NA
Coinciding Route Indicator	Yes/Route	NA
Coinciding Route — Minor Route Information	Yes /Route	NA
Direction of Inventory	Yes	NA

Appendix (F): Potential of technologies to collect MIRE elements (Cont.)

Attributes	Utah Column/Inentory Names/Collection Method	Rating Mannual data collection From Arial Imagry
Segment Classification		
Functional Class	Yes/HPMS sample	NA
Rural/Urban Designation	Yes/HPMS sample	NA
Federal Aid/Route Type	Yes/HPMS sample	NA
Access Control	Yes/HPMS sample	NA
Segment Cross Section		
Surface Type	Yes/HPMS sample	NA
Total Paved Surface Width	Yes/HPMS sample	NA
Surface Friction		NA
Surface Friction Date		NA
Pavement Roughness/Condition	Yes/UDOT pavement cores/Auto	NA
Pavement Roughness Date	Yes/UDOT pavement cores/Auto	NA
Pavement Condition (Present Serviceability Rating)	yes/pavement /Auto	NA
Pavement Condition (PSR) Date	yes/pavement /Auto	NA
Number of Through Lanes	Yes/Lanes(2014)/Auto	NA
Outside Through Lane Width	yes/lanes/Auto	NA
Inside Through Lane Width	yes/lanes/Auto	NA
Cross Slope		NA
Auxiliary Lane Presence/Type	Yes/Lanes/Auto	NA
Auxiliary Lane Length	Yes/Lanes/Auto	NA
HOV Lane Presence/Types	Yes/Lanes/Auto	NA
HOV Lanes	Yes/Lanes/Auto	NA
Reversible Lanes		NA
Presence/Type of Bicycle Facility	Yes/Lanes/Auto	NA

Appendix (F): Potential of technologies to collect MIRE elements (Cont.)

Attributes	Utah Column/Inentory Names/Collection Method	Rating Mannual data collection From Arial Imagry
Segment Cross Section (Cont.)		
Width of Bicycle Facility	Yes/Bike Lanse/Auto	NA
Number of Peak Period Through Lanes	yes/UDOT HPMS Samples2014	NA
Right Shoulder Type	Yes/Shoulders/Auto	2
Right Shoulder Total Width	Yes/Shoulders/Auto	3
Right Paved Shoulder Width	Yes/Shouler/Auto	NA
Right Shoulder Rumble Strip Presence/Type	Yes/Rumblestrips/Auto	2
Left Shoulder Type	Yes/Shoulders/Auto	3
Left Shoulder Total Width	Yes/Shoulders/Auto	NA
Left Paved Shoulder Width	Yes/Shoulders/Auto	NA
Left Shoulder Rumble Strip Presence/Type	Yes/Rumblestrips/Auto	NA
Sidewalk Presence	Yes/Driveways(2014)/Auto	NA
Curb Presence	Yes/Pavem Sect Data-Current	NA
Curb Type	Yes/Pavem Sect Data-Current	NA
Median Type	Yes/Medinas(2014)/Auto	3
Median Width	Yes/Medinas(2014)/Auto	2
Median Barrier Presence/Type	Yes/Barriers(2014)/ Auto	3
Median (Inner) Paved Shoulder Width	Yes/Medinas(2014)/Auto	NA
Median Shoulder Rumble Strip Presence/Type	Yes/Rumblestrips/Auto	NA
Median Sideslope	NA	NA
Median Sideslope Width	NA	NA
Median Crossover/Left Turn Lane Type	NA	NA

Attributes	Utah Column/Inventory Names/Collection Method	Rating Manual data collection From Arial Imagery
Segment Roadside Descriptors		
Roadside Clear Zone Width	Yes/shoulders	3
Right Side slope	NA	NA
Right Side Slope Width	NA	NA
Left Side slope	NA	NA
Left Side Slope Width	NA	NA
Roadside Rating	NA	NA
Major Commercial Driveway Count	Yes /Driveways (2014)/Auto	NA
Minor Commercial Driveway Count	Yes/Driveways (2014)/Auto	NA
Major Residential Driveway Count	Yes/Driveways (2014)/Auto	NA
Minor Residential Driveway Count	Yes/Driveways (2014)/Auto	NA
Major Industrial/Institutional Driveway Count	Yes/Driveways (2014)/Auto	NA
Minor Industrial/Institutional Driveway Count	Yes/Driveways (2014)/Auto	NA
Other Driveway Count	Yes/Driveways (2014)/Auto	NA
Terrain Type	Yes/HPMS sample	NA
Number of Signalized Intersections in Segment	Yes/Intersection (2014)/Auto	NA
Number of Stop-Controlled Intersections in Segment	Yes/Intersection (2014)/Auto	NA
Number of Uncontrolled/Other Intersections in Segment	Yes/Intersection (2014)/Auto	NA

Appendix (F): Potential of technologies to collect MIRE elements (Cont.)

Attributes	Utah Column/Inentory Names/Collection Method	Rating Manual data collection From Arial Imagery
Segment Traffic Flow Data		
Annual Average Daily Traffic (AADT)	Yes/HPMS sample	NA
AADT Year	Yes/HPMS sample	NA
AADT Annual Escalation Percentage	Yes/AADT(Open data)	NA
Percent Single Unit Trucks or Single Truck AADT	Yes/AADT(Open data)	NA
Percent Combination Trucks or Combination Truck AADT	Yes/AADT(Open data)	NA
Percentage Trucks or Truck AADT	Yes/AADT(Open data)	NA
Total Daily Two-Way Pedestrian Count/Exposure		NA
Bicycle Count/Exposure	yes/Bicycle lanes	NA
Motorcycle Count or Percentage		NA
Hourly Traffic Volumes (or Peak and Offpeak AADT)		NA
K-Factor	Yes/HPMS sample	NA
Directional Factor	Yes/HPMS sample	NA
Segment Traffic Operations/Control Data		
One/Two-Way Operations	Yes/HPMS sample	3
Speed Limit	Yes/HPMS sample	NA
Truck Speed Limit		NA
Nighttime Speed Limit		NA
85th Percentile Speed		NA
Mean Speed		NA
School Zone Indicator	Yes	3
On-Street Parking Presence	Yes	3
On-Street Parking Type	Yes	NA
Roadway Lighting	Yes/ roadway utilites	NA
Toll Facility	Yes/HPMS sample	NA
Edgeline Presence/Width	Yes/Medinas(2014)/Auto	4
Centerline Presence/Width	Yes/shouldes	3
Centerline Rumble Strip Presence/Type	Yes/Rumblestrips/Auto	NA
Passing Zone Percentage	Yes/lanes	NA

Appendix (F): Potential of technologies to collect MIRE elements (Cont.)

Attributes	Utah Column/Inentory Names/Collection Method	Rating Manual data collection From Arial Imagery
Other Supplemental Segment Descriptors		
Bridge Numbers for Bridges in Segment	Yes/UDOT Structure (Open Data)	NA
Horizontal Curve Data		
Curve Identifiers and Linkage Elements		NA
Curve Feature Type		NA
Horizontal Curve Degree or Radius		NA
Horizontal Curve Length		NA
Curve Superelevation		NA
Horizontal Transition/Spiral Curve Presence		NA
Horizontal Curve Intersection/Deflection Angle		NA
Horizontal Curve Direction		NA
Vertical Grade Data		NA
Grade Identifiers and Linkage Elements	Yes/Route Grades/Man	NA
Vertical Alignment Feature Type	Yes/Route Grades/Man	NA
Percent of Gradient	Yes/Route Grades/Man	NA
Grade Length	Yes/Route Grades/Man	NA
Vertical Curve Length	Yes/Route Grades/Man	NA

Appendix (F): Potential of technologies to collect MIRE elements (Cont.)

Attributes	Utah Column/Inentory Names/Collection Method	Rating Manual data collection From Arial Imagery
At-Grade Intersection/Junctions		
Unique Junction Identifier	Yes/Intersection(2014)/Auto	NA
Type of Intersection/Junction	Yes/Intersection(2014)/Auto	NA
Location Identifier for Road 1 Crossing Point	Yes/Intersection(2014)/Auto	NA
Location Identifier for Road 2 Crossing Point	Yes/Intersection(2014)/Auto	NA
Location Identifier for Additional Road Crossing Points	Yes/Intersection(2014)/Auto	NA
Intersection/Junction Number of Legs	Yes/Intersection(2012)/Auto	NA
Intersection/Junction Geometry	NA	NA
School Zone Indicator	Yes	NA
Railroad Crossing Number	NA	NA
Intersecting Angle	NA	NA
Intersection/Junction Offset Distance	yes/intersection	5
Intersection/Junction Traffic Control	Yes/traffic	NA
Signalization Presence/Type	Yes/Intersection(2014)/Auto	3
Intersection/Junction Lighting	Yes/ intersection	4
Circular Intersection Number of Circulatory Lanes	NA	NA
Circular Intersection Circulatory Lane Width	NA	NA
Circular Intersection Inscribed Diameter	NA	NA
Circular Intersection Bicycle Facility	NA	NA

Appendix (F): Potential of technologies to collect MIRE elements (Cont.)

Attributes	Utah Column/Inentory Names/Collection Method	Rating Manual data collection From Arial Imagery
Approach Descriptors (Each Approach)		
Intersection Identifier for this Approach	Yes/Intersection(2012)/Auto	NA
Unique Approach Identifier	Yes/Intersection(2012)/Auto	NA
Approach AADT	Yes/AADT	NA
Approach AADT Year	Yes/AADT	NA
Approach Mode	NA	NA
Approach Directional Flow	NA	NA
Number of Approach Through Lanes	Yes/lanes	NA
Left Turn Lane Type	Yes/lanes	NA
Number of Exclusive Left Turn Lanes	Yes/lanes	NA
Amount of Left Turn Lane Offset	Yes/lanes	5
Right Turn Channelization	Yes/lanes	NA
Traffic Control of Exclusive Right Turn Lanes	NA	NA
Number of Exclusive Right Turn Lanes	Yes/lanes	NA
Length of Exclusive Left Turn Lanes	Yes/lanes	NA
Length of Exclusive Right Turn Lanes	Yes/lanes	NA
Median Type at Intersection	Yes/median	4
Approach Traffic Control	NA	NA
Approach Left Turn Protection	Yes/lanes	NA
Signal Progression	Yes/signal	NA
Crosswalk Presence/Type	NA	NA
Pedestrian Signalization Type	Yes/signal poles	NA
Pedestrian Signal Special Features	NA	NA
Crossing Pedestrian Count/Exposure	NA	NA
Left/Right Turn Prohibitions	NA	NA
Right Turn-On-Red Prohibitions	NA	NA
Left Turn Counts/Percent	Yes/lanes	NA
Year of Left Turn Counts/Percent	Yes/lanes	NA
Right Turn Counts/Percent	Yes/lanes	NA
Year of Right Turn Counts/Percent	Yes/lanes	NA
Transverse Rumble Strip Presence	Yes/Rumble	NA

Appendix (F): Potential of technologies to collect MIRE elements (Cont.)

Attributes	Utah Column/Inentory Names/Collection Method	Rating Manual data collection From Arial Imagery
Circular Intersection Entry Width	NA	NA
Circular Intersection Number of Entry Lanes	NA	NA
Circular Intersection Presence/Type of Exclusive Right Turn Lane	Yes/intersetion	NA
Circular Intersection Entry Radius	NA	NA
Circular Intersection Exit Width	NA	NA
Circular Intersection Number of Exit Lanes	NA	NA
Circular Intersection Exit Radius	NA	NA
Circular Intersection Pedestrian Facility	NA	NA
Circular Intersection Crosswalk Location	NA	NA
Circular Intersection Island Width	NA	NA
Unique Interchange Identifier	Yes/ intersection	NA
Location Identifier for Road 1 Crossing Point	NA	NA
Location Identifier for Road 2 Crossing Point	NA	NA
Location Identifier for Additional Road Crossing Points	NA	NA
Interchange Type	Yes/intersetion	NA
Interchange Lighting	Yes/intersetion	3
Interchange Entering Volume	NA	NA
Interchange Identifier for this Ramp	NA	NA
Unique Ramp Identifier	Yes/ADA Ramp Inventory/man	NA
Ramp Length	Yes/facility type	NA
Ramp Acceleration Lane Length	NA	NA
Ramp Deceleration Lane Length	NA	NA
Ramp Number of Lanes	Yes/ADA Ramp inventory	NA
Ramp AADT	NA	NA
Year of Ramp AADT	NA	NA
Ramp Metering	Yes/ADA Ramp inventory	NA
Ramp Advisory Speed Limit	NA	NA
Roadway Type at Beginning Ramp Terminal	Yes/ADA ramp inventory	NA
Roadway Feature at Beginning Ramp Terminal	NA	NA
Location Identifier for Roadway at Beginning Ramp Terminal	Yes/ADA ramp inventory	NA
Location of Beginning Ramp Terminal Relative to Mainline Flow	NA	NA
Roadway Type at Ending Ramp Terminal	Yes/ADA ramp inventory	NA
Roadway Feature at Ending Ramp Terminal	NA	NA
Location Identifier for Roadway at Ending Ramp Terminal	Yes/ADA RAMP inventory	NA
Location of Ending Ramp Terminal Relative to Mainline Flow	NA	NA

Appendix G

A COMPREHENSIVE LISTING OF SAFETY DATA ELEMENTS WITH RANKS

Gaps	MIRE R	HPMS FE	HSM R	MMUCC	Rank	Collected By LIDAR at UDOT
MIRE Attributes						
Segment Location Linkage						
Specific Governmental Ownership	0	0	0	0	0	
City/Local Jurisdiction Urban Code					0	
Coinciding Route — Minor Route Information	0	0	0	0	0	
Segment Cross Section					0	
Surface Friction	0	0	0	0	0	
Surface Friction Date	0	0	0	0	0	
Outside Through Lane Width (HSM R)	0	0	1	0	1	Yes
Inside Through Lane Width (HSM R)	0	0	1	0	1	Yes
Cross Slope (HSM R)	0	0	1	0	1	Yes
Auxiliary Lane Length (HSM R)	0	0	1	0	1	Yes
Reversible Lanes	0	0	0	0	0	
Presence/Type of Bicycle Facility	0	0	0	0	0	
Width of Bicycle Facility	0	0	0	0	0	
Right Paved Shoulder Width (HSM R)	0	0	1	0	1	Yes
Right Shoulder Rumble Strip Presence/Type	0	0	0	0	0	
Left Paved Shoulder Width (HSM R)	0	0	1	0	1	Yes
Left Shoulder Rumble Strip Presence/Type	0	0	0	0	0	
Curb Type	0	0	0	0	0	
Median Shoulder Rumble Strip Presence/Type	0	0	0	0	0	
Median Sideslope	0	0	0	0	0	
Median Sideslope Width	0	0	0	0	0	
Median Crossover/Left Turn Lane Type	0	0	0	0	0	

Appendix (G): A comprehensive listing of safety data elements with ranks (Cont.)

Gaps	MIRE R	HPMS FE	HSM R	MMUCC	Rank	Collected By LIDAR at UDOT
MIRE Attributes						
Segment Roadside Descriptors					0	
Roadside Clearzone Width	0	0	0	0	0	
Right Sideslope (HSM R)	0	0	1	0	1	No
Right Sideslope Width	0	0	0	0	0	
Left Sideslope (HSM R)	0	0	1	0	1	No
Left Sideslope Width	0	0	0	0	0	
Roadside Rating (HSM R)	0	0	1	0	1	No
Major Commercial Driveway Count (HSM R)	0	0	1	0	1	Yes
Minor Commercial Driveway Count (HSM R)	0	0	1	0	1	Yes
Major Residential Driveway Count (HSM R)	0	0	1	0	1	Yes
Minor Residential Driveway Count (HSM R)	0	0	1	0	1	Yes
Major Industrial/Institutional Driveway Count (HSM R)	0	0	1	0	1	Yes
Minor Industrial/Institutional Driveway Count (HSM R)	0	0	1	0	1	Yes
Other Driveway Count (HSM R)	0	0	1	0	1	Yes
Segment Traffic Flow Data					0	
AADT Annual Escalation Percentage	0	0	0	0	0	
Total Daily Two-Way Pedestrian Count/Exposure	0	0	0	0	0	
Bicycle Count/Exposure	0	0	0	0	0	
Motorcycle Count or Percentage (HPMS FE)	0	1	0	0	1	NA

Appendix (G): A comprehensive listing of safety data elements with ranks (Cont.)

Gaps	MIRE R	HPMS FE	HSM R	MMUCC	Rank	Collected By LIDAR at UDOT
MIRE Attributes						
Segment Traffic Operations/Control Data					0	
Truck Speed Limit	0	0	0	0	0	
Nighttime Speed Limit	0	0	0	0	0	
85th Percentile Speed	0	0	0	0	0	
Mean Speed	0	0	0	0	0	
School Zone Indicator	0	0	0	0	0	
On-Street Parking Presence (HSM R)	0	0	1	0	1	Yes
Roadway Lighting (HSM R)	0	0	1	0	1	Yes
Edgeline Presence/Width	0	0	0	0	0	
Centerline Presence/Width	0	0	0	0	0	
Centerline Rumble Strip Presence/Type (HSM R)	0	0	1	0	1	Yes
Horizontal Curve Data					0	
Curve Identifiers and Linkage Elements (HSM R)	0	0	1	0	1	NA
Curve Feature Type (HSM R)	0	0	1	0	1	NA
Curve Superelevation (HSM R)	0	0	1	0	1	NA
Horizontal Transition/Spiral Curve Presence (HSM R)	0	0	1	0	1	NA
Horizontal Curve Intersection/Deflection Angle	0	0	0	0	0	
Horizontal Curve Direction	0	0	0	0	0	

Appendix (G): A comprehensive listing of safety data elements with ranks (Cont.)

Gaps	MIRE R	HPMS FE	HSM R	MMUCC	Rank	Collected By LIDAR at UDOT
MIRE Attributes						
Vertical Grade Data					0	
Grade Identifiers and Linkage Elements (HSM R)	0	0	1	0	1	Yes
Vertical Alignment Feature Type (HSM R)	0	0	1	0	1	Yes
Vertical Curve Length	0	0	0	0	0	
At-Grade Intersection/Junctions					0	
Unique Junction Identifier (MIRE FDE) (HSM R)	1	0	1	0	2	Yes
Intersection/Junction Number of Legs (HSM R)	0	0	1	0	1	Yes
School Zone Indicator	0	0	0	0	0	
Intersection/Junction Offset Distance	0	0	0	0	0	
Intersection/Junction Traffic Control (MIRE FDE) (HSM R)	1	0	1	0	2	Yes
Signalization Presence/Type	0	0	0	0	0	
Intersection/Junction Lighting (HSM R)	0	0	1	0	1	Yes
Circular Intersection Number of Circulatory Lanes	0	0	0	0	0	
Circular Intersection Circulatory Lane Width	0	0	0	0	0	
Circular Intersection Inscribed Diameter	0	0	0	0	0	
Circular Intersection Bicycle Facility	0	0	0	0	0	
Approach Descriptors (Each Approach)					0	
Intersection Identifier for this Approach (HSM R)	0	0	1	0	1	Yes
Unique Approach Identifier (MIRE FDE) (HSM R)	0	0	1	0	1	Yes

Appendix (G): A comprehensive listing of safety data elements with ranks (Cont.)

Gaps	MIRE R	HPMS FE	HSM R	MMUCC	Rank	Collected By LIDAR at UDOT
MIRE Attributes						
Approach Descriptors (Each Approach) Cont.						
Approach AADT (HSM R)	0	0	1	0	1	NA
Approach AADT Year (HSM R)	0	0	1	0	1	NA
Approach Mode	0	0	0	0	0	NA
Approach Directional Flow (HSM R)	0	0	1	0	1	Yes
Number of Approach Through Lanes (HSM R)	0	0	1	0	1	
Left Turn Lane Type	0	0	0	0	0	
Number of Exclusive Left Turn Lanes (HSM R)	0	0	1	0	1	Yes
Amount of Left Turn Lane Offset	0	0	0	0	0	
Right Turn Channelization (HSM R)	0	0	1	0	1	NA
Traffic Control of Exclusive Right Turn Lanes	0	0	0	0	0	
Number of Exclusive Right Turn Lanes (HSM R)	0	0	1	0	1	Yes
Length of Exclusive Left Turn Lanes	0	0	0	0	0	
Length of Exclusive Right Turn Lanes	0	0	0	0	0	
Median Type at Intersection	0	0	0	0	0	
Approach Traffic Control	0	0	0	0	0	
Approach Left Turn Protection (HSM R)	0	0	1	0	1	Yes
Signal Progression	0	0	0	0	0	
Crosswalk Presence/Type	0	0	0	0	0	
Pedestrian Signalization Type	0	0	0	0	0	

Appendix (G): A comprehensive listing of safety data elements with ranks (Cont.)

Gaps	MIRE R	HPMS FE	HSM R	MMUCC	Rank	Collected By LIDAR at UDOT
MIRE Attributes						
Approach Descriptors (Each Approach) Cont.						
Pedestrian Signal Special Features	0	0	0	0	0	
Crossing Pedestrian Count/Exposure	0	0	0	0	0	
Left/Right Turn Prohibitions	0	0	0	0	0	
Right Turn-On-Red Prohibitions (HSM R)	0	0	1	0	1	Yes
Left Turn Counts/Percent	0	0	0	0	0	
Year of Left Turn Counts/Percent	0	0	0	0	0	
Right Turn Counts/Percent	0	0	0	0	0	
Year of Right Turn Counts/Percent	0	0	0	0	0	
Transverse Rumble Strip Presence	0	0	0	0	0	
Circular Intersection Entry Width	0	0	0	0	0	
Circular Intersection Number of Entry Lanes	0	0	0	0	0	
Circular Intersection Presence/Type of Exclusive Right Turn Lane	0	0	0	0	0	
Circular Intersection Entry Radius	0	0	0	0	0	
Circular Intersection Exit Width	0	0	0	0	0	
Circular Intersection Number of Exit Lanes	0	0	0	0	0	
Circular Intersection Exit Radius	0	0	0	0	0	
Circular Intersection Pedestrian Facility	0	0	0	0	0	
Circular Intersection Crosswalk Location	0	0	0	0	0	
Circular Intersection Island Width	0	0	0	0	0	

Appendix (G): A comprehensive listing of safety data elements with ranks (Cont.)

Gaps	MIRE R	HPMS FE	HSM R	MMUCC	Rank	Collected By LIDAR at UDOT
MIRE Attributes						
Approach Descriptors (Each Approach) Cont.						
Interchange and Ramp Descriptors					0	
Interchange Type (MIRE FDE)	1	0	0	0	1	Yes
Interchange Lighting	0	0	0	0	0	
Interchange Entering Volume	0	0	0	0	0	
Interchange Identifier for this Ramp	0	0	0	0	0	
Ramp Acceleration Lane Length	0	0	0	0	0	
Ramp Deceleration Lane Length	0	0	0	0	0	
Ramp Metering	0	0	0	0	0	
Ramp Advisory Speed Limit	0	0	0	0	0	
Roadway Feature at Beginning Ramp Terminal	0	0	0	0	0	
Location of Beginning Ramp Terminal Relative to Mainline Flow	0	0	0	0	0	
Roadway Feature at Ending Ramp Terminal	0	0	0	0	0	

Appendix (G): A comprehensive listing of safety data elements with ranks (Cont.)

Gaps	MIRE R	HPMS FE	HSM R	MMUCC	Rank
MMUCC Attributes					
Case Identifier	0	0	0	1	1
Crash Classification	0	0	0	1	1
II Vehicle Data Elements				1	1
V6. Motor Vehicle Model Year	0	0	0	1	1
V7. Motor Vehicle Model	0	0	0	1	1
V15. Total Lanes in Roadway	0	0	0	1	1
V16. Roadway Alignment and Grade	0	0	0	1	1
V22. Bus Use	0	0	0	1	1
V23. Hit and Run	0	0	0	1	1
V28. Vehicle Configuration**	0	0	0	1	1
V29. Cargo Body Type**	0	0	0	1	1
V30. Hazardous Materials (Cargo Only)**	0	0	0	1	1
III Person Data Elements					0
III-A Level 1: All Persons Involved					0
P4. Person Type	0	0	0	1	1
P5. Injury Status	0	0	0	1	1

Appendix (G): A comprehensive listing of safety data elements with ranks (Cont.)

Gaps	MIRE R	HPMS FE	HSM R	MMUCC	Rank
MMUCC Attributes					
III-B Level 2: All Occupants					0
P8. Restraint Systems / Motorcycle Helmet Use	0	0	0	1	1
III-CLevel 3: All Drivers				1	1
P11. Driver License Jurisdiction	0	0	0	1	1
P16. Driver Distracted By	0	0	0	1	1
III-D Level 4: All Drivers and Non-motorists					0
P17. Condition at Time of the Crash	0	0	0	1	1
P18. Law Enforcement Suspects Alcohol Use	0	0	0	1	1
P20. Law Enforcement Suspects Drug Use	0	0	0	1	1
P21. Drug Test	0	0	0	1	1
III -E Level 5: Non-Motorists (includes occupants of motor vehicles not in transport					0
and occupants of non-motor vehicle transportation devices)	0	0	0	1	1
P22. Non-Motorist Number	0	0	0	1	1
P23. Non-Motorist Action/Circumstance Prior to Crash	0	0	0	1	1
P27. Unit Number of Motor Vehicle Striking Non-Motorist	0	0	0	1	1
IIII Derived and Linked Data Elements					0
CD3. Number of Motorists	0	0	0	1	1
CD4. Number of Non-Motorists	0	0	0	1	1
CD5. Number of Non-Fatally Injured Persons	0	0	0	1	1
CD7. Alcohol Involvement	0	0	0	1	1
CD8. Drug Involvement	0	0	0	1	1
CD9. Day of Week	0	0	0	1	1

Appendix (G): A comprehensive listing of safety data elements with ranks (Cont.)

Gaps	MIRE R	HPMS FE	HSM R	MMUCC	Rank
MMUCC Attributes					
IV Person Data Elements Derived From Collected Data					0
Person Data Elements Obtained After Linkage to Other Data					0
Level 3: All Drivers					0
PL3. Drug Test Result	0	0	0	1	1
Level 6: All Injured Persons					0
PL5. Injury Diagnosis	0	0	0	1	1
Roadway Data Elements Obtained After Linkage to Other Data					0
RL1. Bridge/Structure Identification Number					0
RL2. Roadway Curvature	0	0	0	1	1
RL3. Grade	0	0	0	1	1
RL4. Part of National Highway System	0	0	0	1	1
RL5. Roadway Functional Class	0	0	0	1	1
RL7. Widths of Lane(s) and Shoulder(s)	0	0	0	1	1
RL8. Width of Median	0	0	0	1	1
RL9. Access Control	0	0	0	1	1
RL10. Railway Crossing ID	0	0	0	1	1
RL11. Roadway Lighting	0	0	0	1	1
RL12. Pavement Markings, Longitudinal	0	0	0	1	1
RL13. Presence/Type of Bicycle Facility	0	0	0	1	1
RL15. Mainline Number of Lanes at Intersection	0	0	0	1	1
RL17. Total Volume of Entering Vehicles	0	0	0	1	1

Appendix H

PYTHON CODE USED FOR AUTOMATIC SEARCH FOR MIRE ELEMENTS IN RIMS “SUMMARY.XLSM”

(SUPPORTED BY MANUAL SEARCH)

```
# Import libraries
import csv
import keyword, difflib

# main part of the program
summaryFile = "Summary.csv"
masterSheetFile ="MIREdAtaList.csv"
fiout = open('mireFDEinRIMS.csv','w')
writer=csv.writer(fiout, delimiter=',',lineterminator='\n')

matchslist=[]
with open(masterSheetFile) as masfile:
        mirelist = masfile.read().split("\n")
        for mline in mirelist:
                mireAtrribs = mline.split(",")
                mireItem = mireAtrribs[1:2]
                mireNames = [x.lower() for x in mireAtrribs[2:3]]
                mireDif = mireAtrribs[3:4]
                mireFDE = mireAtrribs[4:5]
                hpmsFE = mireAtrribs[6:7]
                hsmR = mireAtrribs[9:10]
```

```
serchKey = ''.join(mireFDE)    # convert list to string
if 'Yes' in serchKey:
        print mireItem[0]," is > ", serchKey
        with open(summaryFile) as sumfile:
```

Appendix (H): Python coding used for automatic search for MIRE elements in RIMS

"Summay.xlsm" (Supported by manual search) (Cont.)

```
         sumlist = sumfile.read().split("\n")
                for sline in sumlist:
                        sumDataInve = sline.split(",")
                        size=sumDataInve[2:3]
                        rows = sumDataInve[4:5]
                        host = [x.lower() for x in sumDataInve]
                        match = difflib.get_close_matches(''.join(mireNames), host)
                        if match:
                                matchs = sumDataInve[0:1]+size+rows+mireNames+mireItem+match
                                writer.writerow(matchs)                # write output matches into cvs file
```

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